The Effect of a Metronome-based Coordination Training Programme on the Fundamental Gross Motor Skills of Children with Motor Development Delays

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Thesis presented in partial fulfilment of the requirements
for the degree of Master of Sport Science
at Stellenbosch University

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December 2009

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the owner of the copyright thereof (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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Abstract

This study investigated the effect of a coordination-training programme on selected fundamental motor skills of children (ages 9 to 12) who were identified as having motor development delays. The group of participants identified included seven boys and one girl.

The study followed an A-B-A reversal design. The intervention was a rhythm-based training programme. The dependent variables were the motor abilities of bilateral coordination, balance and upper-limb coordination, assessed using the BOT-2. The results of an ANOVA for dependent groups indicated a significant improvement in bilateral coordination and no change in balance. The improvement in upper-limb coordination was attributed to a familiarisation or learning effect on the test. A descriptive analysis of each child's results revealed high variability in the effect of participation in the programme.

The results of this study supported the conclusion that a rhythm-based coordination-training programme may help children with coordination problems improve their bilateral coordination, which will have a positive impact on the performance on many fundamental gross motor skills.

Key words: motor coordination; coordination problems; rhythmic entrainment.

Opsomming

Hierdie studie het die effek van ‘n koördinasie-inoefeningsprogram op die geselekteerde fundementele motoriese vaardighede van kinders (9-12 jaar) ondersoek wat geïdentifiseer is met vertraagde motoriese ontwikkeling. Die geïdentifiseerde groep deelnemers sluit sewe seuns en een dogter in.

Die studie het ‘n A-B-A omgekeerde ontwerp gevolg. Die intervensie was ‘n ritmies-gebaseerde inoefeningsprogram. Die afhanklike veranderlikes was die motoriese vaardighede van bilaterale koördinasie, balans en boonste ledemate-koördinasie wat geassesser is deur middel van BOT-2. Die resultate van ‘n ANOVA vir afhanklike groepe dui ‘n beduidende verbetering aan in bilaterale koördinasie en geen verandering in balans nie. Die verbetering in boonste ledemate-koördinasie kan toegeskryf word aan vertroudheid met of leereffek van die toets. ‘n Beskrywende analise van elke kind se resultate het ‘n hoë veranderlikheid aan die lig gebring op die effek van deelname in die program.

Die resultate van hierdie studie ondersteun die gevolgtrekking dat ‘n ritmies-gebaseerde koördinasie-inoefeningsprogram kinders met koördinasieprobleme kan help om hulle bilaterale koördinasie te verbeter wat ‘n positiewe impak sal hê op prestasie tydens verskeie fundamentele groot motoriese vaardighede.

Sleutelterme: motor coordination; coordination problems; rhythmic entrainment

Acknowledgements

I would like to acknowledge the following individuals and institutions for their invaluable contribution to the completion of this dissertation.

- Professor E.S. Bressan
- The children who took part in the study
- Mr. September and his staff
- Professor M. Kidd
- The National Research Foundation
- The Ernst and Ethel Eriksen Trust
- Mrs. Mari Grobler

Content

List of Figures

List of Tables

Chapter One

Introduction

The term rhythm is widely used to describe a range a different things (Overy & Turner, 2009) therefore consensus on the precise use of all the terminology associated with rhythm is a topic far beyond the scope of this research. According to Barsch (in Thomas & Moon, 1976) the term rhythm is used to describe events that are both universal and individual in nature. He described four basic types of rhythm that are most often referred to in the literature. These include:

1. “Cosmic rhythm or the cyclic nature of the universe;
2. Biological rhythm or repeated physiological patterns normally under control of the autonomic nervous system;
3. Perceived-reproduced rhythm which includes perception of a rhythmic stimulus followed by the subject reproducing the pattern;
4. Performance rhythm which includes consistent replication of a movement pattern with both spatial and temporal accuracy.” (Thomas & Moon, 1976:20)

Perceived-reproduced rhythm and performance rhythm are the types of rhythm dealt with in this study.

Rhythm and Coordination

Rhythm is often linked to auditory processing. A number of studies have found that auditory rhythmic cues appear to exert an attractor effect on the timing of motor responses, which can be observed when people listen to music or rhythms as they spontaneously move to the beat either by drumming fingers, swaying or tapping feet (Grahn & Brett, 2009; Grahn & Brett, 2007; Molinari *et al.*, 2007; Repp & Penel, 2004; Thaut *et al.*, 1999). This phenomenon is known as auditory sensorimotor synchronisation (Molinari *et al.*, 2007).

In the study of Thaut *et al.* (1999) the connection between rhythmicity and brain functioning was explored. They found in their rehabilitation work that the motor system is highly sensitive to auditory rhythmic stimuli, which they proposed created stable internal reference intervals that guided the timing of motor responses. From this perspective, rhythmic stimuli could encourage the entrainment of neural impulses, which would enhance the stability of movement patterns. This stability of movement patterns is associated with movement coordination (Davids *et al.*, 2008).

Movement coordination is needed for the performance of motor skills, ranging from sport situations to activities of daily living. Haywood & Getchell (2009) stated that there are typical developmental pathways governed by the interaction of an individual's genetic predisposition and extrinsic factors, *e.g.* experiences that influence development of the neuromotor and musculoskeletal systems. These pathways are reflected in expected sequences of development through which individuals are expected to progress, and although they appear to be related to age, they are not determined by age (Parker & Larkin, 2003). Individual differences in development lead to a range of variations in motor skill acquisition within the same age-group (Haywood & Getchell, 2005). However there are some children for whom learning and acquiring motor skills is difficult. These children appear to struggle with the coordination of their movements (Parker & Larkin, 2003).

Parker and Larkin (2003) noted that many different labels have been used to identify motor coordination difficulties, including clumsiness, dyspraxia, poor coordination, developmental lag, developmental delay and developmental coordination disorder. They concluded that whatever the label, movement difficulties potentially lead to motor development problems which in turn can have serious negative consequences for the children involved. They contended that strategies to limit the long-term negative effects of coordination problems should be found. Children with movement difficulties follow a different developmental pathway when compared to the "typical" pathway, but they argued that programmes and instructional strategies could be found that could help each child progress on his/her unique pathway toward the achievement of his/her movement potential. Because children who have deficits in their motor coordination compared to their peer group, have been shown to struggle with the rhythmicity and timing of their movement patterns (Ben-Pazi, 2007; Liemohn, 1983), programmes and instructional strategies that focus on rhythm hold promise for some children with movement difficulties.

Purpose of the Study

The purpose of this study is to explore the effects of a rhythmic entrainment programme that took the form of a metronome-based training programme on some of the underlying abilities that support coordinated movement. The selected variables are bilateral coordination, balance and upper-limb coordination. The auditory rhythmic entrainment capabilities and characteristics of humans as well as the importance of rhythm and timing to motor control have led other researchers to explore the capacity to which this interaction can contribute to improvements in movement performance (Thaut *et al.*, 1999). It is hoped that this research will add to that body of knowledge.

Research Questions

The following research questions guided this study:

1. What are the effects of participation in a metronome-based training programme on the *bilateral coordination* of children who appear to have motor development delays?

2. What are the effects of participation in a metronome-based training programme on the *balance* of children who appear to have motor development delays?

3. What are the effects of participation in a metronome-based training programme on the *upper-limb coordination* of children who appear to have motor development delays?

4. What are the effects of participation in a metronome-based training programme on the bilateral coordination, balance and upper-limb

coordination of *individual children* who display motor development delays?

Significance of the Study

Childhood is a critical time for the development of fundamental gross motor skills. This period is considered to be a sensitive learning period for motor skill development (Foweather *et al.*, 2008; Gallahue & Donnelly, 2003; Goodway & Branta, 2003) because there is substantial neurological capacity available for learning fundamental skills (Goddard Blythe, 2000). Fundamental skills serve as a base for learning more complex motor skills and the failure to develop and refine fundamental movement skills during this crucial period can contribute to difficulty in learning more specialised skills later on in life (Foweather *et al.*, 2008; Getchell, 2006; Okely & Booth, 2004; Zachopoulou *et al.*, 2004; Goodway & Branta, 2003; Sanders & Kidman, 1998).

Learning these skills is not only vital but children also enjoy learning them (Zachopoulou *et al.*, 2004; Derri *et al.,* 2001a). Children who experience development delays or who, through lack of experience, are not able to keep up with their peer in the learning of fundamental skills, are often left out of some childhood activities. There is evidence that adding rhythm to movement programmes and the training of rhythmicity and timing can contribute to improved motor coordination and influence the ability to perform fundamental motor skills (Bartscherer & Dole, 2005; Jacokes, 2004; Zachopoulou *et al.*, 2004; Libkuman *et al.*, 2002; Derri *et al.*, 2001a; Shaffer *et al.*, 2001; Zachopoulou & Mantis, 2001; Brown *et al.*, 1981; Beisman, 1967). Although it appears that all children can benefit from movement programmes that are enhanced by including rhythmic elements, it is important that the children who have motor coordination difficulties be given specialised attention so that they can improve their motor performance.

Fundamental Skills

As children mature, coordination patterns become more consistent and stable (Getchell, 2006). The development of mature fundamental skills requires that children be exposed to the opportunity, encouragement and environment so that these skills develop beyond the elementary stage of performance (Goodway & Branta, 2003; Gallahue & Donnelly, 2003; Derri *et al.*, 2001a). Children should be allowed to perform and explore a variety of movement experiences to encourage fundamental skill development. By acquiring these essential skills children can develop their bodies while fulfilling their natural desire for movement (Derri *et al.*, 2001a). Delays in the development of the fundamental motor skills can compromise all other areas of functioning (Goddard Blythe, 2000).

Bilateral Coordination

Bilateral coordination is an underlying ability required for many motor skills. This requires individuals to coordinate the homologous and non-homologous limbs on the same side and opposite sides of the body. Limbs need to be coupled (perform the same function) or decoupled (perform separate functions) when performing movement (Davids *et al.,* 2008). For example, when performing a one handed catch, only the hand involved in catching the ball must move toward the ball and perform the catch while the other hand remains still. Motor skills involving bilateral coordination often require that the limbs involved in the movement move with different spatial and temporal characteristics (Magill, 2003). Bilateral coordination also requires that all the limbs work in synchrony, *e.g.* skills such as jumping and hopping require bilateral coordination (Liemohn, 1983).

Motor coordination problems become particularly noticeable when different limbs are involved in the movement, such as bimanual coordination tasks (Cardoso de Oliveira, 2002). Children who are clumsy are known to struggle with tasks that require bimanual coordination (Williams & Woollacott, 1997; Geuze & Klaverboer, 1994) Therefore, by potentially improving the ability to bilaterally coordinate the different sides of the body it is possible that there will be improvements in the coordination of those motor skills that require bilateral coordination.

Balance

Balance is a critical component of every almost every movement (Goddard Blythe, 2000; Williams & Woollacott, 1997; Burton & Davis, 1992). Balance, both static and dynamic, has been identified as a common deficit in children who exhibit motor control deficits (Williams & Woollacott, 1997). The ability to balance is central to being able to control motor performance. Regardless of the goal of the movement, a movement can be divided into two phases, the preparatory phase and executory phase (Williams & Woollacott, 1997). During the preparatory phase the stability of the system is established, upon which the execution of the movement can be based (Williams & Woollacott, 1997). If the balance of an individual is not good, the subsequent movement may not be adequate (Williams & Woollacott, 1997). The study by Williams and Woollacott (1997) led the authors to conclude that that the balance deficits observed in children who were categorised as clumsy, were due to a motor control system dysfunction, and not a delay in development. The balance deficit was proposed to be a due to a more general timing problem because the patterns of muscle activation in response to postural perturbations appeared to be inappropriate and variable, which they also hypothesise is linked to the more general problem observed during other movement sequences.

According to Goddard Blythe (2000), relatively simple school readiness assessments require children to balance on one leg. This is an indication of whether balance control is adequately established so that the motor system can concentrate on more complex skills. When children have poor balance they have poor body control, which means they have to focus their attention on maintaining equilibrium rather than other things (Cheatum & Hammond, 2000). This not only decreases the amount of attention that can be given to learning new skills which further leads to perceived developmental delays, but it also impacts negatively on classroom and academic tasks. Therefore an individual’s ability to balance is an underlying ability that must receive attention when designing motor development programmes (Parker & Larkin, 2003; Burton & Davis, 1992).

Upper-limb Coordination

Manipulative tasks requiring the control of objects are basic elements of children’s play (Parker & Larkin, 2003) as well as the foundation for specialised movement skills. These fundamental skills include throwing and catching. Throwing and catching involve eye-hand coordination abilities that require the accurate processing of visual information as well as the motor precision of hand, upper-limb and whole-body coordination movements (Gallahue & Donnely, 2003; Magill, 2003). For these skills, perception is a vital component in the outcome of the task and catching in particular requires the control of spacio-temporal variables (Savelsbergh *et al.*, 2003). There are many problems that are characteristic of poor performance of these tasks that are common among children with motor difficulties (Parker & Larkin, 2003).

Throwing is a basic fundamental movement pattern used in many different sports, which makes the acquisition of an efficient throwing action important. Children with movement difficulties often show inefficient throwing patterns because their coordination patterns and timing of the motion sequences are poor (Parker & Larkin, 2003).

Catching is a complex task as it requires the individual to use visual information to adapt to the flight of the ball and predict where to place the hands and when to grasp the ball (Gallahue & Donnelly, 2003; Parker & Larkin, 2003). If any of the sequences involved in catching are mistimed the resultant movement is inefficient or results in the failure to secure the ball (Parker & Larkin, 2003).

Movement Competence

Perceptions of movement competence are recognised to have an influence on the psychosocial aspects of children's lives (Skinner & Piek, 2001; Rose *et al.*, 1997). Skinner and Piek (2001) stated that poor motor coordination has significant implications for social and emotional functioning since poor coordination has been linked to attention disorders, low self-esteem, poor self-concept and emotional disorders. This makes the development of movement competence a significant dimension of a child's holistic development.

According to Harter's (1987) model of competence motivation, the major goal of achievement behaviour is the need to feel competent. Competence is considered to be the individual's level of mastery, which can range from poor to superior. Children's perceived competence of their motor ability affects their continued interest to participate in movement experiences and in further mastery attempts (Skinner & Piek, 2001). If children have low self-perceptions of motor competence then they often choose not to participate. Children who have poor motor skills are likely to experience frustration (Sanders & Kidman, 1998) and to have low levels of perceived movement competence because of their repeated failure at movement tasks (Skinner & Piek, 2001; Rose *et al.*, 1997).

Low perceptions of movement competence can in turn initiate a vicious cycle because children may start to avoid opportunities where motor skills can be practised as well as avoid social interaction because they fear peer criticism and failure. These behaviours will result in a decrease in their practise time and their motor skills will not improve (Piek *et al.*, 2006; Skinner & Piek, 2001; Rose *et al.*, 1997). These observations tie in with the Developmental Skill-Learning Gap Hypothesis proposed by Wall (2004), in which children who are not able to perform the gross motor skills enjoyed by their peers, eventually experience a degree of social alienation from the peer group as the skill gap widens. This leads to children who have poor motor skills finding it difficult to participate in a meaningful and beneficial way which in turn leads to them finding it even more difficult to acquire the skills that they require (Wall, 2004).

Motor competence does not only impact on the athletic domain, but has broader implications for the development of children's self-perceptions about other domains in their lives (Skinner & Piek, 2001; Rose *et al.*, 1997). Therefore it is important for children to be allowed to develop their movement proficiency so that they can experience more positive perceptions of their motor competence (Ulrich, 1987).

Active Lifestyle

Children who have poor fundamental motor skills self-select to avoid participation in physical activity and as a consequence, the likelihood of their leading a physically active lifestyle is reduced (Booth *et al.*, 1999). It is important that fundamental motor skills be learned in order to lay the foundation for lifetime participation in sport and recreation (Sanders & Kidman, 1998). Results from a study by Okely *et al.* (2001) found a significant link between the ability to perform fundamental movement skills and participation in organised physical activity amongst adolescents. This finding is supported by a study by Ulrich (1987) who found that children who participated in organised sport were more competent than those who did not participate. This was to be expected, as skilled individuals are more likely to participate in physical activity because they perceive themselves as competent and will extract more enjoyment from the experience. Alternatively, those who participate in organised physical activity are more likely to receive instruction and practise and therefore become more skilled. This reciprocal relationship emphasises the importance of developing movement skills especially during the childhood years where children readily learn skills (Okely *et al.*, 2001).

Sport participation and physical activity during childhood and adolescence have been shown to be significant predictors of physical activity in adulthood (Telama *et al.*, 2005; Perkins *et al.*, 2004; Tammelin *et al.*, 2003). Exposure to positive physical activity experiences at a young age can lead to the formation of healthy habits and development of the necessary physical skills to make exercise an enjoyable experience. The likelihood of becoming and staying active as an adult is highly dependent on the individuals past experiences of physical activity (Hills *et al.*, 2007; Shephard, 1997).

Practical Considerations

It is essential that training programmes be designed to address the problems of movement coordination and lack of proficiency in performing fundamental motor skills. Movement education programmes have the potential to allow children to develop their motor abilities, master fundamental skills and subsequently benefit from an active lifestyle. However, these types of programmes need to be cost and time effective so that they can be implemented at any school over a short period of time. This study was designed to address these practical considerations. The training sessions were relatively short therefore easy to administer during school break periods. The intervention period of the study was also short in order to minimise negative impact on the other subjects in the school curriculum.

Methodology

This study followed an A-B-A reversal design (Thomas & Nelson, 2001). The experimental group was composed of eight children between the ages of 9 and 12. The group consisted of seven boys and one girl. Three subtests, bilateral coordination, balance and upper-limb coordination, of the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2), were used to assess the children's gross motor skills. The intervention took the form of a metronome – based training programme that consisted of 11 sessions over a period of three weeks. Each child came individually to the training sessions. The training programme required the child to perform pre-determined rhythmic movements in time to a beat. Group data was analysed using the ANOVA for dependent groups. Changes in motor performance were considered statistically significant at $p < 0.05$. The individual data was also analysed descriptively on a case-by-case basis.

Limitations

The following limitations have affected the outcome of this research:

- Although the BOT-2 is a universally accepted measurement instrument for motor proficiency, it is not possible for any single test to measure all categories of motor skills. Therefore, the results of the test must be considered an indication of gross motor skill proficiency rather than a comprehensive profile (Burton & Miller, 1998).

- The BOT-2 has its limitations in that it places a limit on the number of potentially correct trials an individual can perform, therefore limiting the discrimination and sensitivity of the test to greater improvement (Burton & Miller, 1998).

- Throwing and catching tasks were part of the BOT-2 assessment of upper-limb coordination. Both skills require good balance as well as bilateral coordination for optimal performance. This interaction among other underlying abilities in the performance of upper-limb coordination tasks makes it a difficult variable to isolate for assessment.

- The time available for training sessions was determined by the practical aspects of the school timetable. This meant that both the amount of time available and the time of day for training were not under control of the researcher. The number of training sessions and the length of each session were, however, consistent among the participants.

- Fewer children than anticipated had sufficiently low scores on the BOT-2 to qualify for invitation to participate in this study. This reality limited the sample size.
- It is well accepted that children do not perform consistently which always must be kept in mind gathering data and interpreting results (Parker & Larkin, 2003).

Delimitations

Although there are many motor variables that affect movement coordination, this research project was restricted to determining the effect of the training programme on three variables that define categories of gross motor skills as set out by the BOT-2: Bilateral coordination, balance and upper-limb coordination.

Definitions

The following definitions of terms were used in this study.

1. Coordination: The organisation of synergies to produce functional movement patterns (Jensen *et al.*, 1994).
2. Coordinative Structures or Synergies: The grouping of muscles and joints that are involved with the specific movement which are constrained to act as a single functional unit (Burton, 1990; Kugler *et al.*, 1982).
3. Developmental Delay, Poor Motor Coordination and Clumsiness: These terms are used interchangeably throughout the text. The terms are used to describe children who experience movement difficulties and who, in comparison to their peers appear to be

delayed in their motor coordination development (Parker & Larkin, 2003).

4. Rhythmic Accuracy: The ability to synchronise ones movement to a rhythmic isochronous beat (Mastrokalou & Hatziharistos, 2007).

5. Rhythmic Entrainment: The development of a stable movement pattern through synchronisation of movement to an isochronous rhythmic cue. In this study the rhythmic cue took the form of an auditory rhythm which was provided by a metronome (Thaut *et al*., 1998).

Summary

Children with poor motor coordination require additional support if they are to achieve their movement skill development potential. Consequently, there is a need to develop effective programmes so that these children can participate successfully in age-appropriate activities. For some of these children, a poor internal sense of rhythm may be a limiting factor in their coordination, and by adding a rhythmic element to their movement education, improvements in motor skills can be achieved.

The aim of this study was to explore the effects of a relatively short, cost-effective rhythmic entrainment programme which took the form of a metronome-based training programme on selected variables underlying motor coordination. The programme was implemented with children who display motor development delays in their performance of fundamental gross motor skills when compared to their peers. The results of the study will contribute to the body of knowledge supporting the impact of rhythmic entrainment programmes as means to enhance the development of coordination.

Chapter Two

Review of Literature

This chapter describes motor control and coordination with reference to two motor control theories. It also looks at the development of coordination and the implications for programme development. Finally it explores the difficulties of children with coordination problems and the role of rhythm-based training in the enhancement of motor skills.

Motor Control and Coordination

Motor control was defined by Salman (2002:5) as the “process of restricting the output of the motor nervous system so that meaningful and coordinated behaviour ensues.” Carson (2006) stated that current models of motor control are based on the premise that there is some kind of hierarchical order to the control of movements in which the motor unit is the most basic structure. The sequence usually begins at the lowest level where selected motor units act together at the muscle level, muscles then act at the joint level, joints combine to act at the limb level, the limbs act together in combinations and the combinations of limbs combine to act together to move the body as a unit (Burton, 1990; Turvey, 1990). Muscle coordination is therefore initially dependent on the organisation of the control of motor units (Carson, 2006; Turvey, 1990).

Coordination was defined by Burton (1990:129) as the “process by which movement components are linked or combined into higher level functional units or coordinative structures.” It is the organisation of movement structures into functional movement patterns (Jensen *et al.*, 1994). Coordinated motor behaviour relies on precise coordinated activation of the many muscles that are responsible for the movement of the multiple joints that are involved in a coordinated movement (Cardoso de Oliveira, 2002). Savelsbergh *et al.* (2003) summarised coordination as the effort to gain control of the degrees of freedom that characterise the interaction among the various components of motor performance.

Coordination depends on a control system that has been postulated to take place at higher levels in the nervous system where the number of independent components is reduced, making the effort involved in applying control strategies more economical (Chow *et al.*, 2008). The lower levels of control are proposed to be linked neurologically which allows for the development of higher level coordinative structures (Burton, 1990). Davids *et al.* (2008) presented the control of coordination in the context of Bernstein's description of the development of functional muscle-joint linkages or synergies to manage the large number of degrees of freedom (Carson, 2006; Turvey, 1990).

Carson (2006) described synergies as functional assemblies of motor components that associate together to perform a common goal. With practise and repetition, more complex synergies are formed that effectively reduce the degrees of freedom, making movement performance easier to manage and regulate (Davids *et al.*, 2008; Salman, 2002; Burton, 1990; Kugler *et al.*, 1982). During initial efforts to gain coordination, "rigid linkages" characterise the relationship among the body parts/components of movement. For example, the locking of certain joints to reduce the many degrees of freedom is a novice's strategy to reducing the overall processing load of coordination performance (Davids *et al.*, 2008). With more practise the initial rigid linkages between the body parts are unfixed as task-specific synergies and coordinative structures are established that increase the degrees of freedom.

The formation of the task-specific synergies leads increased movement efficiency and economy. As the coordinative structures become more flexible (increasing the degrees of freedom leads to decreased rigidity) they can be reassembled to achieve different goals and may be adapted to meet the challenges presented by a dynamic environment (Davids *et al.*, 2008). There have been a number of different theories proposed to describe the process of motor control and the development of coordination. One approach, considered to be a traditional approach, is from an information processing perspective (Schema Theory) and the other is a more contemporary approach that falls under the broad description of an Ecological Perspective (Dynamic Systems Theory) (Haywood & Getchell, 2009). These approaches will be explored in the following section.

Schema Theory

Schema Theory as initially proposed by Schmidt (1975) provides an information-processing perspective on the learning and control of motor skill performance. The premise of the Schema Theory is the existence of generalised motor programmes (GMPs) that serve as the memory framework for different classes of movements (Shumway-Cook & Woollacott, 2007; Magill, 2003; Schmidt, 2003). A specific GMP will contain the rules for creating the temporal and spatial patterns of muscle activity that are required for a specific movement pattern (Shea & Wulf, 2005). These rules function as parameters for shaping motor commands that are invariant despite the context in which movements are performed (Schmidt, 2003). These parameters are thought to be rigid structures of a GMP and are proposed to include relative timing, relative force and sequence (order) of the components involved in the movement performance (Schmidt, 2003). When performing movements from the same class, the same GMP provides the same parameters for relative timing, force and the sequence of movement components.

In order to adjust performance to different contexts, a second memory structure was proposed: The recall schema (Schmidt, 2003). Magill (2003) described the parameters stored in the recall schema as variant, including optional commands for moderating the overall timing (duration), overall force, and the specific muscles and body parts used to perform a skill. He went on to describe the control of movement performance in this approach as the matching of a GMP with a recall schema in order to send optimal combinations of commands to the muscles. For example, once a GMP is learned for a class of movements, such as the overhand throw, the recall schema to support overhand throwing in a variety of contexts could continue to expand with experience.

Schmidt (2003) highlighted the development of schemas to generate appropriate parameter characteristics to attach to the GMP every time a movement is performed. He noted that when learning a new skill, establishing the GMP is critical because it defines the conceptual framework for subsequent performance. This framework includes the relative timing among the components of the movement performance as well as the relative force among components.

Establishing a recall schema is equally important because it will control the adaptation of the GMP to meet the demands of a specific performance context, which will include modifications in the overall speed or rate of performance of the entire movement as well as the force of the movements and the specific body parts involved. In the Schema Theory, both the relative timing among components and the overall timing of performance to the demands of the environment are critical (Magill, 2003).

Dynamic Systems Theory

Haywood and Getchell (2009) identified the Dynamic Systems approach as part of the Ecological Systems perspective on the development of motor control and coordination. This approach views an individual as a complex system that functions as the interaction of many sub-systems. The interactions among the sub-systems are proposed to “self-organise” in order to support the functioning of the system, *i.e.* the individual (Davids *et al.*, 2008). Within the context of motor performance, self-organisation is a process of establishing coordinative structures that will allow the individual to adapt his/her movement patterns to achieve his/her goal (Davids *et al.*, 2008; Magill, 2003).

Rather than propose a hierarchical structure for coordination that is controlled by a central memory structure such as the GMP with its schemas, a self-organising model is conceived in which the coordinative structures for motor performance emerge from the interaction among the individual, the environment and the skill (Goodway & Branta, 2003; Ishee, 2003). The behaviour of the system, in this case an individual moving to achieve a goal, is shaped by constraints that are relevant in a particular situation (Davids *et al.*, 2008).

Several authors use Newell’s model proposing three kinds of constraints that influence the organisation of movement performance: Individual constraints, task constraints and environmental constraints (Haywood & Getchell, 2003). The implication of this approach is that the coordinative structures that enable motor performance will be shaped in response to the interaction among individual, task and environmental constraints (Goodway & Branta, 2003).

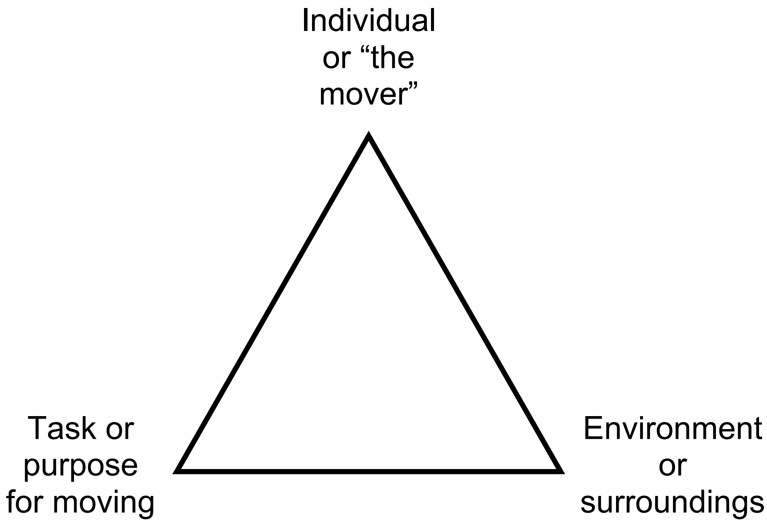


Figure 1. Newell's (in Haywood & Getchell, 2009) model of the Ecological approach to understanding motor control.

Individual Constraints

Individual constraints are the physical and mental characteristics that are unique to an individual which shape their behaviour (Davids *et al.*, 2008; Haywood & Getchell, 2005; Goodway & Branta, 2003). These constraints can be either structural or functional.

Structural Constraints

Structural constraints are related to an individual's body structure. These constraints are relatively resistant and slow to change, although change does occur with growth and aging (Haywood & Getchell, 2005). These constraints include characteristics such as height, weight, synapse connections in the brain, neuromuscular pathways, and neurological development (Davids *et al.*, 2008; Haywood & Getchell, 2005; Goodway & Branta, 2003).

Functional Constraints

Functional constraints are related to an individual's behavioural function. These constraints change relatively easily and in a short space of time. These include motivation, emotions, cognitions, memory, rhythm and focus of attention (Davids *et al.*, 2008; Haywood & Getchell, 2005; Goodway & Branta, 2003).

Environmental Constraints

Environmental constraints are the physical or sociocultural variables of the surroundings, and are not task specific.

Physical Constraints

Physical constraints are characteristics of the environment such as the temperature, lighting and gravity (Davids *et al.*, 2008; Haywood & Getchell, 2005; Goodway & Branta, 2003).

Sociocultural Constraints

The sociocultural environment of an individual can play a large role in encouraging and discouraging behaviour (Haywood & Getchell, 2005). These constraints include social variables such as family support, peer groups, societal expectations and attitudes, and cultural norms (Davids *et al.,* 2008; Haywood & Getchell, 2005; Goodway & Branta, 2003).

Task Constraints

Task constraints are external to the individual's body but are specific to the performance context. These include (Davids *et al.*, 2008; Haywood & Getchell, 2005):

Goal of the Task

The goal of the movement.

Regulatory Conditions

The rules which govern the activity, equipment, surfaces and line markings.

Constraints and Movement Coordination

In terms of the Dynamic Systems Theory coordination can be seen as the patterning of the body and limb motions relative to the environmental and task-goal conditions (Turvey, 1990). Davids *et al.* (2008) explained that in different situations and under different circumstances, individual, environmental and task constraints set the boundaries that either restrict or facilitate successful movement performance. If a constraint is so critical to movement performance that it potentially could impede the emergence of effective movement performance, it is labelled “a rate limiter or rate controller” (Haywood & Getchell, 2005:20). The impact of rate limiters must be managed if the performer is to successfully achieve his/her goal.

The Development of Coordination

The following section discusses the presence of stability and attractors in addition to control and order parameters within the development of coordination patterns. Timing and rhythm are important features of good coordination and are presented here as abilities underlying coordination, along with a discussion on timing and how it relates to the two different theories of motor control.

Stability and Attractors

One operational premise of a dynamic system is its tendency to seek stability. Magill (2003) refers to stability as the preferred behavioural state of a system. After a small perturbation the system seeks to return to the stable behavioural state. Shumway-Cook & Woollacott (2007) described these stable states as well entrained systems, *i.e.* the coordinative structures organise into a stable pattern of interaction that enables movement performance. Stable states are labelled “attractor states” and they are associated with the preferred movement patterns of an individual (Davids *et al.*, 2008; Magill, 2003).

Shumway-Cook and Woollacott (2007) used the analogy of attractor “wells” to explain the relative stability of different movement patterns. They explained that the more stable the movement pattern, the deeper the attractor well, and the deeper the well, more difficult it is to change the behaviour of the system. They identified changes in stability states, also called phase transitions, as substantial changes in movement behaviour. For example, developing skilfulness in the overhand throw calls for several phase transitions to develop from novice to expert performance levels. Their conclusion was that if an attractor well is relatively shallow, the attractor state can shift and a new stable state can be formed more easily than if the attractor well is deep.

Order Parameters and Control Parameters

Van Emmerik (2007) described order parameters as specific variables that define the interaction of all the systems involved with the performance of a specific movement pattern. An example of an order parameter is the relative phase between the movements of parts within a specific movement (Magill, 2003).

Shumway-Cook & Woollacott (2007) described control parameters as specific variables that regulate changes in the system. Examples of control parameters are variables such as force, tempo or speed (Magill, 2003). Control parameters can regulate frequent changes, depending on the constraints that impact on performance. Control parameters can be manipulated to influence the stability of the system and can even change the character of one or more of the order parameters (Magill, 2003). For example, when a control parameter is changed beyond a certain critical boundary, the coordinative relationships within the system will give way to a new coordinative structure (Phillips & Clark, 1997).

Underlying Abilities of Coordination

Coordination abilities were identified by Büsch and Strauss (2005) as major determinants of achievement in the motor domain, which is why the development of coordination is critical during childhood (Getchell, 2006). Skilled movements require that limbs be precisely coordinated (Cardoso de Oliveira, 2002). Good timing and rhythm are underlying features of good coordination and are seen as important factors in the development, learning and performance of motor skills (Mastrokalou & Hatziharistos, 2007; Derri *et al.*, 2001a; Geuze & Klaverboer, 1994; Smoll & Schutz, 1978; Thomas & Moon, 1976).

Timing

One characteristic of skilled motor performance is the control parameter that specifies the timing of the muscular actions that govern the relationship among the synergies. Motor control and timing are inextricably linked and the goal of good timing is the optimal synchronisation of synergies (Salman, 2002). When performing a movement the relevant motor units have to be activated at the correct times in the right sequences with the precise parameters for movements to be precise and accurate (Mauk & Buonomano, 2004; Ivry & Hazeltine, 1995; Williams *et al.*, 1992).

Coordinated movement requires both spatial accuracy and temporal accuracy (Smoll, 1974b). The movement of various segments of the body involves the displacement of segments to different areas in space, and this displacement takes a certain amount of time (Smoll, 1974a).

Coordination of movement relies on accuracy in the temporal relationship among the limbs as well as the spatial accuracy of the limbs (Cordo *et al.*, 1993). The correct timing of activation for force generation as well as an appropriate amplitude of the force for each muscle contraction is needed for coordinated movement (Salman, 2002). Any error in the temporal or spatial execution of any of the parts of a movement can result in inaccurate movement. Improvement in the control of the time and space aspects of a movement can improve the accuracy of the performance (Mazyn *et al.*, 2007; Keele *et al.*, 1985).

According to Zachopoulou & Mantis (2001), individuals who have an optimal internal representation of time have the ability to perform movements in a smoothly coordinated fashion. In everyday behaviour as well as skilled performance, timing is paramount to the optimal performance of movements especially when the movements have to be adjusted to meet the demands of a dynamic environment (Tyldesley & Whiting, 1975). Tyldesley and Whiting (1975) propose that if the timing of the motor plan, or the temporal pattern, is not optimally selected and implemented by the motor system, the movement will not be accurate. As individuals advance from novice to more expert performance, their overall temporal and spatial patterning improves, and the resultant movement performances become more consistent and stable (Tyldesley & Whiting, 1975). This is in contrast to novices who are typically inconsistent in their control of the temporal and spatial aspects of performance, leading to their performance attempts being less successful. This is similar to the pattern observed in clumsy children, where the spatial and temporal aspects of performance are inconsistent, and movement attempts are less successful, and without intervention these individuals never do progress to the expert phase as their timing remains inconsistent.

Rhythm

A firm grasp of the concept of time is the foundation on which rhythmic ability is based (Zachopoulou & Mantis, 2001). Rhythm can operate as a control parameter affecting the relationship among the space and time components of performance which influence the accuracy of movement performance (Ben-Pazi *et al.*, 2007; Schwanda, 1969). Within the context of this study, rhythmic accuracy is defined as “the synchronisation of body movements to a rhythmic stimulus” (Mastrokalou & Hatziharistos, 2007:902). Rhythmic performance is dependent on both spatial and temporal accuracy as the body parts must be at a specific point in space at a specific time (Schwanda, 1969). Rhythmic auditory and visual motor performance is defined as the execution of a set movement sequence to rhythmic patterns perceived through audition or vision respectively (Huff, 1972).

Rhythm has been traditionally acknowledged to be a special type of timing that underlies the acquisition and performance of motor skills (Derri *et al.*, 2001; Smoll & Shultz, 1978; Thomas & Moon, 1976; Smoll, 1974a; Bond, 1959). Rhythmic ability is thought to be an intrinsic sense that affects the manner of motor performance (Mastrokalou & Hatziharistos, 2007). According to Mastrokalou and Hatziharistos (2007:901) rhythmic ability refers to the comprehension, memorisation and presentation of the “temporal-dynamic” structure of movement, and therefore an individual’s rhythmic ability, which is based in the internal representation of time, affects the way in which motor movements are performed. Rhythmic ability has been described as the ability to consistently perform regulated gross motor movements with both spatial and temporal accuracy (Derri *et al.*, 2001b; Thomas & Moon, 1976) integrated with the ability to perceive a rhythmic stimulus (Mastrokalou & Hatziharistos, 2007).

The qualities of skilful movement typically include reference to the appearance of being unhurried, fluent and flowing (Shaffer, 1982; Huff, 1972; Schwanda, 1969). However, Schwanda (1969) was convinced that the “rhythm” of a skilful performance does not appear to be the same as “rhythm” when used in referring to music. Huff (1972) described a performer who is less talented, has less skill or appears clumsy tends to appear awkward and “lacks rhythm.” She conducted a study to determine whether there were differences between auditory and visual perception of rhythm whether differences in perceptions of rhythm were related to the performance of gross motor skills as performed by skilled performers in basketball, dancing, swimming and modern dance compared to a control group of non-athletes. She found there to be a substantial variation in the visual rhythmic response of all the respondents, and dancers where not found to have a better rhythmic perception compared to the control group. A significant difference between the control group and the skilled athletes indicated that the skilled athletes performed a gross motor sequence to both auditory and visual rhythms more accurately. She concluded that skilled athletes exhibit a rhythmic organisation in their movement.

Timing and Theories of Motor Control

A common feature of both the traditional information processing theories such as Schema Theory and the contemporary Dynamic System Theory is the importance given to the timing and relative timing. Within the GMP of Schema Theory the relative timing of a movement pattern is seen as an invariant parameter which results in the same timing constraints across all movements using the same GMP. Dynamic Systems Theory uses the phrase “temporal pattern” which is an order parameter (similar to the invariant parameter of the Schema Theory) distinguishing one movement pattern from another pattern. The invariance of the temporal pattern is however seen to emerge from the dynamic interactions among the systems involved in the movement. If the temporal pattern remains stable across different control parameters the coordination among the systems are considered to be well entrained (Magill, 2003).

The presence of temporal patterns in movement has led researchers who follow information processing models to theorise about the mechanisms of an internal timekeeper. Although they generally agree about the presence of an internal timekeeper or internal reference of time, there are differences in terms of their concepts about the means of time perception and production (Bartscherer & Dole, 2005, McAuley & Jones, 2003; Ivry, 1996; Ivry & Hazeltine, 1995). Ivry and Hazeltine (1995) argued that the existence of an internal timekeeper was supported by the results of their research. They found that a stable internal representation of time could be entrained by performing repetitive target intervals in time with an external beat, and that the internal beat could be maintained even when the external stimulus was removed. From their results they concluded that movement performance depends on establishing and internal reference interval and if an impact can be made on the internal timekeeper, an individual's movement performance can be improved.

Advocates of Dynamic Systems Theory proposed that timing control is not regulated by an internal timekeeper, but rather that timing control is an emerging property of performance in a particular context, where the intrinsic dynamics of the system govern the timing of the movement (Volman & Geuze, 1998; Collier & Wright, 1995). During movement the spacio-temporal properties of the movement emerge due to the dynamic processes involved in the neuromuscular system (Ivry, 1996; Ivry & Hazeltine, 1995).

Implications for Programme Development

The following section discusses the stages of motor learning in the acquisition of motor control. It also looks at the entrainment characteristics of movement performance and how rhythm relates to entrainment.

Stages in the Development of Coordinated Movement

Davids *et al.* (2008) provided a comprehensive description of the development of coordinated movement from a Dynamic System Theory perspective. They described the development of coordination as a process of trying to achieve stable and functional movement patterns that are effective in achieving the goals of specific tasks. Using the terminology of Dynamic Systems Theory, individuals attempt to create attractor states to organise coordinative structures into different movement patterns. As an individual gains experience in a variety of movement situations, they develop a large collection of movement attractors. This collection of attractors has been labelled the perceptual-motor landscape.

Davids, *et al.* (2008) continued to explain that the perceptual-motor landscape is in continual transformation. The development of the landscape is a reflection of the interaction among the constraints that characterise the various movement experiences of the individual. For example, the movement capabilities which individuals possess are a source of constraints that impact the learning of a new skill. Temporary attractor states (shallow attractors) characterise the perceptual-motor landscape of novices. Learning and practise result in the emergence of increasingly refined solutions to the movement problem, which leads to strengthened connections amongst the coordinative structures involved in the movement. The more efficient and successful coordination patterns increase in stability, that is the attractor wells deepen, and the individual is more able to adapt to the changing constraints of tasks and environments. At the same time the less successful patterns are discarded. Davids *et al.* (2008) concluded their description by summarising the development of coordination as a process in which the perceptual-motor landscape changes as some attractor wells deepen and others become shallower.

Both Chow *et al.* (2008) and Davids *et al.* (2008) advocated the use of Newell’s model of three stages of motor learning as a novice-to-expert presentation of the acquisition of motor control. They link the stages of learning to the progressive reorganisation of the perceptual-motor landscape as attractor states are modified in response to changing constraints in movement performance situations.

Stage 1: Coordination

The coordination stage sees the learner establish basic relationships between the motor system components to achieve the movement goal (Chow *et* *al.*, 2008). The individual constructs a movement through assembling the relative limbs and trunk movements into the correct sequences (Davids *et al.*, 2008). Children's movements' mature and fundamental skills develop as they develop the ability to coordinate the actions of their separate limbs into a cooperative whole. This coordination relies on the coupling and decoupling of limbs as well as controlling the degrees of freedom (Getchell, 2006).

Stage 2: Control

The second stage is where exploration of the movement pattern under different conditions takes place. Davids *et al.* (2008) stated that once the movement actions are established the parameter values of the coordinative structures are explored through repeated practice under variable conditions. This stage sees the degrees of freedom of a movement pattern become more flexible. Movement control in this stage involves the assignment of overall parameter values to particular coordinative structures (Chow *et al.*, 2008; Burton, 1990). The features that are parameterised include variables such as displacement, speed, force, size, amplitude and timing (Jensen *et al.,* 1994; Burton, 1990). During this stage of learning, the attractor stability is strengthened through variations of movement patterning so that an individual becomes more adaptable to different conditions. This leads to the strengthening of the adaptability of attractor states under changing circumstances (Chow *et al.*, 2008).

Stage 3: Skill

In this stage the performer becomes more adept at using information provided by environmental sources and being able to adapt their movement (Davids *et al.*, 2008). Skilled behaviour arises when optimal parameter values are assigned to the variables required for the movement (Chow *et al.*, 2008). The optimisation of the coordinative structures enhances efficiency and control of movement patterns. Individuals become capable of flexible and efficient actions and are able to utilise these to provide the optimal solution to movement situations (Davids *et al.*, 2008).

Chow *et al.* (2008) discovered that with practise, novices progress from the coordination stage to the control stage as their movement patterns showed evidence of reforming into different configurations which lead to improved movement control. However, they also found that novices did not experience a clean sequential progression through the stages. They cautioned that there are no strict boundaries between the stages and individuals are continually exploring different movement solutions to perform the movements optimally.

Entrainment

From a Dynamic Systems Theory perspective, the perceptions, memories, plans and actions that characterise movement performance are “self-organising macroscopic patterns formed by the interactions of the many system components” (Davids *et al.*, 2008:p39). The functioning of each subsystem is thought to be fairly autonomous as each subsystem tends towards equilibrium or stability and therefore self-organises (Schmidt *et al.*, 1992).

An example of Dynamic Systems Theory is the conception of inter-limb coordination as the coupling of nonlinear, limit-cycle oscillators (Whitall, 1989). The coupling is characterised by entrainment or “phase locking” (the coupled synchrony of each oscillator) and the subsequent emergence of structural stability. Whithall (1989) specified that phase locking occurs when oscillators are attracted to certain phase modes in which their functioning remains stable. For inter-limb coordination, phase locking involves the well-entrained specific relationships in temporal and amplitude phasing.

Whithall (1989) continued to explain that after a small perturbation the oscillators within the dynamic system phase lock and re-entrain to the closest stable phase. However, if a perturbation is large enough, phase transitioning occurs where the oscillators entrain to a new and different attractor state and the phasing relationship changes. She concluded by stating that in a developing system, such as that of a child, phase transitions can take place by manipulation of a system that is relatively sensitive to change (even a small perturbation can cause a transition). The disruption of the dynamic stability leads to a new coordination phase which would be initially unstable, until the phasing becomes entrained within the system.

Rhythm and Entrainment

Mastrokalou and Hatziharistos (2007) associated the development of fundamental motor skills with the development of rhythmic ability. They investigated whether age, gender and tempo of the rhythm have an effect on rhythmic ability. Their results showed that there were no differences between boys and girls' rhythmic ability at either slow or fast tempo. These results are in agreement with other early studies involving children of different ages (Smoll & Schultz, 1978; Thomas & Moon, 1976; Smoll, 1975a). Zachopoulou *et al.* (2003) reported that some researchers have found that rhythmic training did not improve the rhythmic ability of young children between the ages of 3 to 9. In addition these authors reported that of the studies they reviewed, two found that maturation, rather than rhythmic training led to improvements in the children's ability to synchronise their movements to a rhythmic stimulus.

According to Merker *et al.* (2009) very little is known about the developmental timeline of human capacity to entrain rhythm. However it is observed that age may have an influence on rhythmic ability in children. As they get older a decrease has been found in temporal deviation and overall rhythmic ability improves (Mastrokalou & Hatziharistos, 2007; Smoll, 1974a). In their discussion of the evolution of the capacity to entrain to an external isochronous beat, Merker *et al.* (2009) observed that the entrainment capacity develops later in childhood, and at ages 6 and 7 children have demonstrated an incompletely developed ability to entrain to auditory rhythms.

Pollatou *et al.* (2005) and Zachopoulou *et al.* (2003) reported that rhythmic ability appears to develop through the ages of 4 to 7, and that with maturation children gain the capacity to effectively react to simple auditory rhythms as well as rhythmic motives. The maturation of the central nervous system's basic functions, especially the time-perception mechanism, is related to the development of rhythmic ability (Mastrokalou & Hatziharistos, 2007; Zachopoulou *et al.,* 2003). Mastrokalou and Hatziharistos (2007) stated that rhythmic training along with physical development leads to the activation of a response mechanism to rhythm and therefore can lead to improved rhythmic ability. These authors suggested that "rhythmic ability enhancement programmes within the elementary school physical education curriculum should be explored further with the aim of improving children's motor development and performance" (Mastrokalou & Hatziharistos, 2007:911).

Some authors have contended that rhythmic ability is genetically determined and therefore cannot be trained, where other authors have argued that rhythmic ability is trainable and can improve after a rhythmic entrainment programme (Zachopoulou *et al.*, 2003; Zachopoulou & Mantis, 2001). Although it is generally recognised that maturation has an affect on the ability of children to synchronise movements to a beat, Huff (1972) found that among adult performers, there is no evidence that training in music or dance contributes to the ability to perceive rhythms and to move to visual or auditory rhythms.

There is some evidence that training can contribute to the development of rhythmic ability. Smoll (1974a:58) concluded, "Rhythmic ability may be enhanced by general and/or specific experiences available to the child". Although individuals appear to have an inherent rhythmic ability based on their internal representation of time (Smoll & Schultz, 1978; Thomas & Moon, 1976; Smoll, 1975b; Smoll, 1975c) the accuracy of rhythmic ability has been improved in some individuals as a result of experience and practise (Zachopoulou *et al.*, 2003; Greenspan, 2002).

Zachopoulou *et al.* (2003) wanted to determine whether a music and movement programme based on the Orff and Dalcroze approach could improve the rhythmic ability of preschool children (ages 4 to 6). They used the High/Scope Beat Competence Analysis Test as their assessment instrument. After a 10-week (35 to 40 minute sessions twice a week) intervention programme, the experimental group's (n = 34) rhythmic ability improved significantly when compared to the control group (n = 38) who participated in free-play activities. These researchers concluded that improving rhythmic ability through movement was possible and that the neuromuscular system could be trained to respond to rhythmic stimuli. They advised that such programmes should contain simple movements and simple rhythms and should involve the activation of large muscle groups.

Children with Coordination Problems

Parker and Larkin (2003) emphasised that children who manifest motor performance difficulties are a heterogeneous group, because many of the children do not exhibit the same motor deficits. They encouraged scientists and practitioners to regard children with coordination problems as unique individuals who may present atypical patterns of development in terms of their motor ability and skill learning. They also reminded those who study or work with children with motor coordination problems that their behaviours are often influenced by the interaction of coordination difficulties with comorbid disorders such as Attention Deficit Disorder (ADD) and learning problems. Comorbidity makes it extremely challenging to conduct research and/or implement programmes.

The following sections briefly describe common difficulties of children who exhibit motor development delays, the relationship of timing and rhythm with poor motor control, and what the possible solutions are for assisting children with coordination difficulties.

Motor Development Delays

Children who exhibit general motor control deficits have been described as having poor control and coordination of simple and complex movements (Williams *et al.*, 1992; Geuze & Klaverboer, 1987). Although motor control problems may have a unique presentation in each individual, there are two difficulties which are commonly experienced by the many children (Williams & Woollacott, 1997):

1. Poor static and dynamic balance;

2. Inappropriate or inadequate use of the limbs in a variety of tasks which require bimanual coordination (Parker & Larkin, 2003; Williams & Woollacott, 1997). Children with poor inter-limb and body coordination have difficulty with integrating upper and lower body movement (Williams & Woollacott, 2007; Williams *et al.*, 1992). This clumsiness is apparent in locomotor skills, object manipulation skills as well as bilateral coordination activities (Williams *et al.*, 1992).

Timing

Timing is a crucial factor of gross motor function and deficits in the timing mechanism may be responsible for the appearance of clumsiness (Geuze & Klaverboer, 1994). Geuze and Klaverboer (1987) demonstrated that children who appear to be clumsy showed an inconsistency in their ability to adapt their timing of simple movements in comparison to a control group. They concluded that children who appear to be clumsy often have a general timing problem that has negative consequences for learning movement patterns.

The link between timing problems and movement coordination difficulties was supported by the findings of Williams *et al*. (1992), who found that clumsy children were significantly more variable in their tapping responses than children in a control group. They also contended that timing deficits are due to central timing mechanisms rather than peripheral mechanisms involved in the movement production. They postulated that one cause of awkward movements is found in the temporal dimension of an internal timekeeper.

Rhythm

Volman and Geuze (1998) found that children who were identified as clumsy had considerably less stable basic coordination patterns than that of matched controls on the performance of rhythmic coordination tasks. This was discovered by the application of perturbations while these children performed both bimanual and visuomanual tasks. The authors suggested a possible reason for the reduced stability of the coordinative structures is that the children identified as clumsy had a weak coupling strength between their oscillators, *i.e.* that their coordinative structures are not tightly formed. They indicated that children who are clumsy are more susceptible to environmental perturbations because they take longer to return to their original attractor after a perturbation. From their Dynamic Systems perspective, Volman and Geuze (1998) inferred that poor coordination is not a result of an underlying neural mechanism (as is suggested by Williams *et al.*, 1992), but rather that reduced stability is due to the weaker coupling of the systems involved. Although many of the clumsy children in the study were identified to have minor neurological problems, the authors indicated that there was no clear relationship found between these signs and the lack of coordination stability.

Liemohn (1983) stated that the development of rhythmic ability, motor coordination and control are interrelated. He also identified participation in locomotor activities as critical for learning of time perception, and noted that problems with an internal timing mechanism may lead to children's lack of rhythmicity which will in turn lead to clumsy movement performance. Ben-Pazi *et al.* (2007) reported that children with developmental disorders have been shown to have abnormal rhythmic tapping responses, which is indicative of a deficient rhythmic accuracy that relates to a lack of an accurate representation of internal time (Bartscherer & Dole, 2005).

In response to the notion that children with learning and motor problems appear to be asynchronous or lack rhythm, Liemohn (1983) conducted a factor analytic study where children's rhythmicity scores on synchronous tapping (hands tapping in time with a beat) tasks appeared to be good predictors of performance on psychomotor skills. These findings support the case that the rhythmicity required to perform the tapping tasks is important when performing psychomotor skills. However, Liemohn (1983) acknowledged that arrythmicity is not only limited to children with coordination difficulties, but that so-called "normal" children who are also arrhythmic may have developed compensatory techniques so that they can perform movements smoothly and rhythmically.

Possible Solutions

Burton (1990) proposed that there are two possible solutions to approaching coordination difficulties. The first solution he proposed is a neuromotor strategy. When children present with coordination difficulties it is highly likely that their neuromotor processes are in some way limited which leads to poor coordination. It must be recognised that in most cases coordination problems are not an isolated phenomenon, but occur along with other motor and sensory deficits. The neuromotor strategy is based on two basic principles, which coincide with the first stages of Newell's model of motor learning.

1. The first principle states that “movement coordination must be developed before movement control” (Burton, 1990:134). This implies that an individual may have coordination without having control over the movement. This means that the individual is able to perform the movement but the control parameter values are not yet assigned. However, an individual cannot have control without coordination. A movement coordination pattern requires that a set control parameters be assigned. In this context movement control is viewed as the ability to perform the coordinated movement pattern across a range of parameter values.

2. The second principle states “movement coordination and control should be developed in a hierarchical sequence” (Burton, 1990:135). Individuals are unique in their development and each individual may have an optimal attractor for a particular movement pattern. An individual may not reach their optimal pattern due to limitations within their neuromotor system. To accommodate these limitations, Burton (1990:135) proposed that individuals systematically perform other movement skills at or near their ‘coordination-level limit’ or perform the same movement skill at a lower level of proficiency by changing the key control parameters in order lower the challenge on coordination.

The second strategy identified by (Burton, 1990) is a mechanical one where mechanical solutions can be temporarily used to assist in learning. In cases where physical or neuromotor limitations make learning impossible, a mechanical strategy can be relatively permanent. These mechanical constraints are usually classed as orthotic or mobility devices. This strategy is outside of the ambit of this study.

Rhythmic Entrainment

Burpee *et al.* (2001) explained the underlying theory of rhythmic entrainment. They proposed that movement coordination and accurate performance are based on an internal sense of rhythm and that an internal sense of rhythm provides a base for timing, which is fundamental to the execution of actions. Motor skill performance requires movement actions to follow in a spatial sequence, but to be effective, the sequence of movements also must follow an effective rhythm. They identified the purpose of auditory rhythmic entrainment as the practice of the timing and rhythm of movements so that their coordination can be improved. In this approach, auditory stimulation is hypothesised to act as an external timekeeper and the internal timekeeper entrains and is stabilised to a more stable attractor state.

Movement programmes involving rhythmic training incorporate other critical movement concepts such as body awareness and space concepts (Zachopoulou *et al*., 2004; Zachopoulou & Mantis, 2001). Body awareness involves the full control of the body as a whole or the various parts and is necessary for the skilful use of the body during rhythmic activities. Practise of space concepts (levels, directions, pathways) are important for learning relationships with equipment and other children (Zachopoulou & Mantis, 2001). Some supporters of auditory rhythmic entrainment have even suggested that improving the vital abilities of timing and rhythm can lead to improvements in the performance of a range of tasks across academic, social and as well as motor skill domains (Bartscherer & Dole, 2005; Greenspan, 2002).

The following sections present previous research in the domain of rhythmic entrainment, the integration of music into movement programmes, the forms of rhythmic stimulation, and the potential benefits of interactive training.

Previous Research

A few studies have demonstrated the effectiveness of auditory rhythmic entrainment using a variety of techniques. Three studies (Bartscherer & Dole, 2005; Jacokes, 2004; Shaffer *et al.*, 2001) determined the effects of metronome-based coordination training programmes which provided concurrent auditory feedback delivered by the Interactive Metronome® (IM) computer programme. The motor skills of children in these studies were measured by the Bruininks-Oseretsky Test for Motor Proficiency. The Jacokes (2004) study involved 13 clients and tracked changes in the dependent variables of balance, bilateral coordination and upper-limb coordination. Significant improvements in balance and bilateral coordination were found directly after the intervention period. These improvements were found to be maintained after a three- and six-month interval.

Shaffer *et al.* (2001) traced the impact of IM training on a total of 58 dependent variables, including bilateral coordination, upper-limb coordination, speed and dexterity, as well as motor control, attention and concentration, academic and cognitive skills. The study involved 56 boys between ages 6 to 12 who had been diagnosed with Attention Deficit Hyperactivity Disorder (ADHD). The children were divided into three groups, of which one group participated in IM training, another group played video games, and the final group formed a control group who received no training over a 3 to 5 week period which included 15 one-hour sessions for each child. Children in the IM group significantly improved on 53 of the 58 variables ($p<0.0001$), the video game group showed significant improvement in 40 of the 58 variables ($p<0.0058$). The control group displayed mixed results and improved on 28 variables while declining on the remaining 30 variables. This led the authors to conclude that the IM and video groups showed significant pattern increases in performance in comparison to the control group.

Bartscherer and Dole (2005) completed a case study involving a 9-year-old boy with attention and motor coordination difficulties. They found that after 15 sessions (over a period of seven weeks) of IM training, the boy made gains in his rhythmic accuracy as measured by the computer programme. They reported that the comparison between the pre- and post-intervention scores on the Bruininks-Oseretsky Test of Motor Proficiency showed positive changes with regard to balance, response speed, and upper limb speed and dexterity. Throughout the training period the boy required progressively less physical assistance to perform the movement in time with the beat. The researchers hypothesised that the training may have had an impact on the internal timekeeper. They concluded that when precision timing is practised, even when performing simple movements, the overall movement coordination ability of an individual is improved.

Studies have been conducted to explore the effects of rhythmic entrainment programmes on specific sport skills. Libkuman *et al.* (2002) investigated the effect of rhythmic entrainment on the accuracy of performance in golf. The study involved both an experimental group (n = 20) who participated in a total 10 hours of the IM training spread over a five-week period and a control group (n = 21) who received 12 pages of golfing tips to be read at least once a day. The results indicated that the experimental group improved significantly in their accuracy of performance in golf. This improvement was consistent across their use of different golf clubs. These authors suggested that the temporal coordination required in golf were improved through training. They speculated that the performance of skills in other sports requiring precision timing would also benefit from IM training.

A study by Zachopoulou and Mantis (2001) was conducted with tennis players (n = 50) between the ages of 8 to 10 years. The forehand ground-stroke was the dependent variable in this study. It was assessed by determining the stability in the performance of the forehand ground-stroke by asking participants to perform the greatest number of forehand ground-strokes on-target within the correct kinematic criteria as specified by the test, at distances of two and three meters. After an initial assessment, the participants were randomly divided into a control group (14 boys and 11 girls) and an experimental group (13 boys and 12 girls). The intervention period lasted 10 weeks where the participants engaged in the physical activities for 16-minute sessions per week.

1. The experimental group participated in locomotor activities that were designed to improve rhythmic accuracy and maintenance of rhythmic tempos. In these sessions the children performed locomotor skills in synchronisation with external rhythmic stimuli. Throughout the programme the children performed single or simple combinations of locomotor skills invented by the child or as set out by the instructor. Some non-locomotor movements were also incorporated.

2. The control group performed warm-up movement activities without any external rhythm or encouragement to attend to internal rhythm.

The forehand ground-stroke of participants in the experimental group significantly improved ($p<0.001$) after the intervention, and there was an improved stability in ground-stroke performance at both distances.

The Zachopoulou and Mantis (2001) study also sought to determine whether rhythmic accuracy and rhythmic maintenance would be influenced by the rhythmic locomotor training. The results revealed that the rhythmic accuracy of the participants in the experimental group improved significantly ($p<0.001$) when compared to the control group who showed no significant change in rhythmic accuracy. Neither group displayed significant changes in their rhythmic maintenance. This confirmed that specialised tennis training alone does not result in improvement in rhythmic accuracy, as well as in demonstrating that rhythmic training can lead to improved rhythmic accuracy, an indication that rhythmic ability can be improved.

Integrated Music and Movement Programmes

The use of music which provides a steady tempo, or a rhythmic beat, has also been explored as an external rhythmic stimulus for movement programmes. These interventions have involved a variety of musical accompaniment techniques, including movement to recorded music, to singing and to musical instrument accompaniment. Music has properties which can provide pleasure and enjoyment to a class which can improve motivation during a class. Although music was not the medium for rhythmic training explored in this study, some studies that have involved the use of music in its various forms will be highlighted to provide further insight into the potential of rhythm to impact on coordination.

A study by Beisman (1967) determined that teaching fundamental motor skills with a rhythmic accompaniment (piano, records, tape recorder, drum, clapping and singing) in comparison to no accompaniment to girls and boys in Grades One to Six (n = 607), resulted in a significant improvement in performance of the selected fundamental movement skills. The motor skills were measured both quantitatively and qualitatively. The intervention lasted 10 weeks, with the rhythmic accompaniment sessions of 10 to 20 minutes each, twice per week. These findings were similar to those of Derri *et al.* (2001a) who conducted a 10-week music and movement programme intervention with preschool children (35 boys and 33 girls) between the ages of 4 to 6. Their intervention was applied twice a week for 35 to 40 minutes each session. The experimental group (n = 35) participated in a music and movement programmes based on the Orff and

Dalcroze approaches to rhythmic education, while the control group (n = 33) participated only in free play activities. They found that the fundamental locomotor skills of the experimental group improved significantly more than those of the control group. The experimental group “almost reached the mature stage of performance on galloping, leaping, horizontal jump, and skipping” (Derri *et al.*, 2001a:22).

Zachopoulou *et al.* (2004) conducted a similar study with preschool children (n = 80) between the ages of 4 to 6 where the outcome variables where jumping and dynamic balance. The intervention programme took place twice a week for between 35 to 40 minutes. The experimental group participated in a music and movement programme (based on the Orff approach), while the control group participated in a non-rhythmic physical education programme. Rhythmic accompaniment during the lessons was the main difference between the two programmes. The activities for both groups include similar amounts of practice with jumping and balancing tasks. The results showed a significant improvement in jumping and dynamic balance of the experimental group as opposed to the control group who showed no significant improvement. The rhythmic accompaniment programme also had a greater effect on dynamic balance than jumping performance. The authors hypothesised that this was due to the coordination patterns for dynamic balance appearing around the age of 4 where as the coordination patterns for jumping are usually only established around the age of 7.

Another study (Brown *et al.*, 1981) involved preschool children (ages 4 to 6). They wanted to determine whether an integrated physical education and music programme (based on Kodaly and Dalcroze concepts such as nursery rhymes being taught through music and singing games) had an effect on perceptual-motor performance. Both the experimental group (n = 15) and control group (n = 15) received 24 sessions (four days a week for 30 minutes) of instruction. While the experimental group participated in the integrated music and movement programme, the control group participated in movement exploration and self-testing activities. The children participating in the integrated music programme showed a significantly greater improvement in their perceptual motor skills compared to the children in the movement exploration and self-testing programme.

The authors suggested that this finding gave merit to the inclusion of music in movement programmes to introduce beat and rhythm, as a means for enhancing the teaching of perceptual-motor skills.

The effect of music as an aid to teaching swimming has also produced interesting results. Dillon (1952) observed that rhythm is an important aspect in both the speed and technique of swimming. She gave one group of swimmers 12 sessions of experimental teaching where music was used at all times when the students were swimming. During the training the tempo of the music was stressed as a cue for executing specific swimming skills. She gave a second group traditional swimming instruction. Her research found that intermediate swimmers, who were instructed with music as accompaniment, improved their form and increased their speed more quickly than those swimmers who were taught without musical accompaniment.

Auditory versus Visual Rhythmic Stimuli

Auditory stimuli in various forms (music, percussion instruments, clapping, metronome, singing etc.) are readily available and can be played in the background while an individual concentrates on performing a task. Auditory rhythms are said to be more familiar to most individuals as they have more experience and practise within this domain and therefore are more readily perceived (Repp & Penel, 2004; Huff, 1972; Rosenbusch & Gardner, 1968).

The auditory system processes sensory information very quickly, and the motoric reproduction on rhythmic patterns is more stable and accurate than other sensory modalities (Thaut *et al.*, 1999). The physiological mechanism for auditory sensorimotor synchronisation is based on the interactions between the auditory and motor systems (Thaut *et al.*, 1999). Sound arouses and excites spinal motor neurons, and thus can stimulate the timing of muscle activation patterns. This has been measured by electromyography (EMG) that has facilitated hopping movements (Thaut *et al*., 1999).

The presence of rhythmic accompaniment is thought to immediately add stability to the motor control of movement. This is due to the symmetrical pulse of the music (or in the case of this study, the metronome) to increase the symmetry of muscle activation (Thaut *et al.,* 1999). A rhythmic facilitation study by Thaut *et al.* (1997) involving the rehabilitation of stroke patients showed that the rhythmic facilitation of gait training significantly improved gait velocity and stride length in comparison to the control group (no rhythmic facilitation). The stride symmetry of the group receiving rhythmic-facilitated training also improved. These authors suggested that the timing symmetry of the rhythm served as a cue for the stroke patients to improve their stride symmetry. Their study supports the existence of physiological mechanisms between the motor system and auditory sensors, such as auditory rhythmic timekeepers that enhance coordinated motor unit recruitment.

In a similar study working with hemiparetic stroke patients, Prassas *et al.* (1997) found that auditory rhythmic facilitation in the form of music had a positive effect on gait characteristics. According to Prassas *et al.* (1997) movement accompanied by auditory rhythms can improve timing and improve the stability by reducing the inconsistency of movement patterns. They based their work on previous research that had found that auditory rhythms appear to improve temporal stride symmetry and reduce the inconsistency of lower limb gait patterns. They also noted that external rhythmic stimuli has been found not only to be effective in the learning of fundamental movement skills, but it has also been demonstrated that learning of movements requiring complex timing requirements or in disorders affecting timing mechanisms the external rhythm acts as an external timekeeper mechanism to assist the brain.

While most studies have used auditory rhythmic stimuli in their training programmes and research about rhythm, some studies have looked at whether there is a difference in the response to visual or auditory stimuli. Rosenbusch & Gardner (1968) found that as children mature (from ages 5 to 12) their rhythmic perception in response to visual and auditory stimuli improves; however, the auditory response was consistently better than the visual response. Huff (1972) compared athletes, dancers and a non-athletic control groups. She found that athletes and non-athletes showed greater variation in their visual perception than in their rhythmic perception. The dancers were the most accurate of all groups in moving to auditory rhythms, while the tennis players in the athletes’ group were the most accurate of all subjects in their response to visual patterns. Huff (1972) concluded that practise and experience with a modality of stimulation has an influence on rhythmic perception.

Thomas and Moon (1976) conducted a study with 5-year-old children (n = 44) to determine the preferred stimulus mode in rhythmical tasks requiring temporal-spatial accuracy. They found that performances to auditory stimuli were much more accurate that those in response to audio-visual and visual stimuli. They suggested that receiving concurrent information via visual stimuli can function as a distraction and decrease the accuracy of the intended movements. When the visual system had less information to process (only the target of the movement) the movement was more accurate. This led the researchers to conclude that children should initially be taught motor tasks requiring high temporal-spatial accuracy with only audio cues. This conclusion was supported by Brown *et al.* (1981).

Summary

This chapter introduced motor control and coordination as it relates to both the Schema Theory, a traditional information processing perspective, and the contemporary Dynamic Systems Theory which falls under the Ecological Systems perspective. The Schema Theory advocates the existence of a hierarchical structure controlled by a central memory structure which governs movement production. The Dynamic Systems Theory views individuals as a complex system that functions as the interaction of many sub-systems. The interactions of the sub-systems are proposed to self-organise to establish the movement patterns of coordinative structures to achieve the goal of the movement.

In the process of the development of coordination the dynamic system has a tendency to seek stability as a preferred behavioural state. These stable states are described as well entrained systems which are seen as the attractor states for the preferred movement pattern. Underlying coordinated movement performance are two features of good coordination which are seen as important factors in the development and learning of motor skills. Timing and rhythm are presented as critical abilities underlying coordination. Timing governs the relationship of the interaction of the coordinative synergies involved in actions, and rhythm affects the temporal-spatial components of performance that influences the accuracy of performance. Both the Schema Theory and the Dynamic Systems Theory agree that timing and relative timing of movements are important for the outcome of movement patterns, although the theories provide different explanations for the regulation of the timing.

In systems that are intact coordinated movement appears to be effortless and it would appear that the entrainment of the movement is optimal and stable. However, in the case of individuals who have coordination problems, the movements do not appear to be well entrained or stable therefore fluctuations occur frequently leading to high variability in movement performance. This would suggest that the attractor state is shallow. Although many constraints within the individual, environment and task may influence the outcome of the movement, the individual's functional and structural constraints would be the major rate limiters for the movement. A premise of this thesis is that uncoordinated movement is to some extent a product of inconsistent synchronisation, rhythm and timing. The individual's rhythmic ability could be seen as a functional constraint. It must be recognised within an individual as well as the task (movement) there are many possible rate limiters, of which rhythm is only one possibility. However an individual's rhythmic ability is a critical constraint of the self-organisation of movement patterns.

Children who appear to have motor developmental delays and coordination difficulties are a heterogeneous group, but there are difficulties which many of them have in common, these include poor balance and inadequate body coordination. Deficits in timing and rhythm have been identified as possible reasons for the appearance of clumsy behaviour. A possible solution to assist in improving coordination difficulties is that one develop a neuromotor strategy which addresses the individuals movement coordination and control.

The underlying theory of rhythmic entrainment proposes that movement coordination and accurate performance is based on an internal sense of rhythm, and by practising timing and rhythm of movements a more stable attractor state is created leading to improved control over movement performances. Previous research has indicated a positive influence using a variety of rhythmic entrainment techniques, including using music integrated into movement programmes, on motor skills of children. Auditory stimuli has also proved to be a more efficient form of rhythmic stimuli than visual stimuli in the learning environment. The benefit of concurrent external feedback has also been shown to enhance movement control during practise and performance.

It can be concluded that it is critical for all children, but especially children with coordination problems, to be exposed to rhythmic stimuli and encouraged to engage in such experiences as an optimal approach to their development of effective coordination (Zachopoulou *et al.,* 2004; Derri *et al.*, 2001a; Zachopoulou & Mantis, 2001). Within the context of this study, the intervention is aimed at influencing sub-systems within the individual's functional constraints that affect the coordination of the individual and thereby improve the performance of key fundamental movement skills. One of the simplest rhythmic movements that can be performed is tapping in synchrony with a rhythmic beat (Corriveau & Goswami, 2009), so the specific intervention of computer-based interactive metronome training has been selected. The premise is that the intervention will look to cause a stable attractor state which will lead to stability within the system.

Chapter 3

Methodology

This chapter describes the research methodology followed in this study, including a description of the design, the research protocol and the plan for the analysis of data and presentation of results.

Design

This study followed a reversal design (Thomas & Nelson, 2001). Watkinson and Wasson (1984) also call this a repeated time-series design. The design chosen was an A-B-A pattern. Criterion-based sampling was used to select eligible participants. Criterion-based sampling is characterised by the participants meeting the requirements necessary to be included in the study as set out by the researcher (Thomas *et al.*, 2005). The reversal design is a quasi-experimental design that has been recommended for use in real-world settings (Thomas *et al.*, 2005). According to Thomas *et al.* (2005), this A-B-A reversal design is characterised by the following:

- A phase where no intervention occurs (A), is followed but an intervention phase (B), then the initial phase is repeated (A).
- The first phase is to established baseline measurement period and is defined as the time between an initial test (test 1) and a pre-test (test 2) to which the impact of the intervention phase (time between test 2 and 3) can be evaluated.
- A retention period where the intervention is withdrawn is established between a post-test (test 3) and the retention test (test 4).

Komaki and Goltz (2001) attributed the strength of this design to the role of the group as its own control, because any changes that might occur are based on comparisons found only within the group. It is a design that controls for history, maturation (Thomas *et al.*, 2005; Watkinson & Wasson, 1984) and selection bias (Thomas *et al.*, 2005) because the same participants are evaluated at the same time during the same time periods. According to Watkinson and Wasson (1984) this design is particularly suitable in studies where the independent variable is suspected as being highly influential. In pharmaceutical research, it is intended for the dependent variable to return to the first baseline measurement after the withdrawal of the intervention in order to demonstrate a relationship between the independent and dependent variable (Shadish *et al.*, 2002, Watkinson & Wasson, 1984). However this design has been frequently used in many skill acquisition studies where the return to the baseline is not desired because learning was intended. Therefore, in the present study the withdrawal phase is used to assess the retention and generalisation of the dependent variable after the intervention has ceased (Watkinson & Wasson, 1984).

Another characteristic of this study that supported the selection of this research design was that the children who participated in the study were described by their teachers as appearing clumsy in comparison to their peers in terms of motor proficiency. The possibility that they might present with a unique combination of movement coordination problems meant that they might respond to a movement intervention programme in unique ways (Haywood & Getchell, 2005). For this reason, it did not seem likely that a control group could be identified. This realisation provided further support for choosing the A-B-A design (see Figure 2).

Shadish *et al.* (2002) cautioned that this research design has disadvantages, for example, it is conducted over a longer period of time than many other studies, which can affect participant motivation. The time period of this an A-B-A design can potentially lead to attrition of participants for a variety of reasons. This was the case in this study as one of the children did not complete the final test (test 4) because she did not come to school for two weeks. Shadish *et al.* (2002) also noted that the repetition of testing procedures can contribute to a practise effect that influences test results as the tests become more familiar to each individual over the period of the study. The items on the assessment instrument were all relatively straight forward and were presented in a simple environment which would not make them particularly attractive to the children to practise in their own time.

<table>
<tr><th colspan="13">13 Weeks</th></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td></tr>
<tr><td>Test 1</td><td colspan="3">Baseline Period (A)
No contact</td><td>Test 2</td><td colspan="3">Intervention Period (B)
Individual sessions</td><td>Test 3</td><td colspan="3">Retention Period (A)
No contact</td><td>Test 4</td></tr>
</table>

Figure 2. An overview for the timeline of this study.

Procedures

The following procedures were implemented in the completion of this study.

Selection of Assessment Instrument

Subtests from the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) (Bruininks & Bruininks, 2005) were selected to become the assessment instrument in this study. The BOT-2 is a standardised, norm-referenced approach which focuses on performance outcomes, rather than the manner in which a skill or movement is performed (Burton & Miller, 1998). The BOT-2 consists of a number of subtests designed to assess the motor proficiency of gross and fine motor skills of children between the ages of 4.5 and 14.5 years of age. It is widely used and recognised as a valid, quick and easy-to-administer test to assess children's motor proficiency (Kambas & Aggeloussis, 2006; Hassan, 2001; Düger *et al.*, 1999; Wilson *et al.*, 1995). The validity and reliability of the test have been supported (Deitz *et al.*, 2007; Wilson *et al.*, 1995). The test-retest reliability coefficient is reported to be between 0.68 to 0.88 for all subtests, except balance (0.64) and the response speed subtest which is not used in this study (Burton & Miller, 1998; Wilson *et al.*, 1995). Deitz *et al*. (2007) reported that the inter-rater reliability coefficient is above 0.9 for all subtests (with the exception of a fine motor subtest). The internal consistency was reported to show moderate to high correlations (Deitz *et al*., 2007; Wilson *et al*., 1995). One weakness of the BOT-2 is that the standard error of measurement (SEM) is relatively large, which has been attributed by Wilson *et al.*, (1995) to the high variability of children's movement production. They suggested that subtest total point scores be used to measure progress rather than the standard scores. Even then the retest scores must exceed the SEM to be confident that a score has in fact changed.

Norm-referenced tests are a popular method for assessment of children's movement abilities. These kinds of tests compare the individual's scores relative to their peers (Burton & Miller, 1998). This makes the BOT-2 useful for screening and evaluating programmes as well as determining eligibility and placement for programmes (Burton & Miller, 1998). Wilson *et al.* (1995) reported that the BOT-2 is recommended as a means for evaluating the effectiveness of motor skill development programmes, and that it is suitable for re-administration within three to four week periods in order to track changes in motor proficiency.

Although the BOT-2 is a very popular assessment instrument, it has a few disadvantages. According to Burton and Miller (1998) the first disadvantage is that valid results depend on how the individuals who are assessed compare to the normative group on which the standards for interpretation are based. The normative group in the case of the BOT-2 only takes into account the chronological age and gender of the individuals, but not the biological age, maturation, height, weight, socioeconomic status, physical and mental impairments. However, they did acknowledge that this test has been used widely around the world. Keeping this in mind, the results of this study were not compared to the BOT-2 norms. The scores attained on the BOT-2 subtests were compared within the group that was assessed. The children with the lowest scores on the BOT-2 were selected from the group of volunteers who had been identified by their teachers, and thereafter their scores were compared only to the baseline scores attained.

Burton and Miller (1998) remarked that an additional weakness of the test was that the scores (raw, scale or composite scores) offered no information about why an individual performed poorly. They felt that the purely quantitative outcome measurements did not provide sufficient information for programme planning. They identified a third disadvantage of using any norm-referenced test to be the use of scores to identify individuals who require further assistance. They felt that there should be scope for interpreting the critical level or minimum standard for a particular score based on the needs and characteristics of each child.

The final two disadvantages identified by Burton and Miller (1998) are the most pertinent to this study. The variability in the performance of children is widely recognised, but the norm-referenced standards of the BOT-2 rely on mean scores from selected reference groups. Some of the subtests of the BOT-2 offer only a fixed number of trials which puts a cap on the maximum score that can be earned, which limits the sensitivity of the subtest to high levels of proficiency. One reason for the popularity of the BOT-2 is that limits the number of trials which makes it more time-efficient to administer. This is a practical consideration in many school settings. The final disadvantage is the positive influence of previous experience with the movements used on some of the subtests on the scores of individuals who take the BOT-2. In this study, the subtests that were selected were comprised of movement activities with which all of the children would be familiar, therefore removing any advantage one child might have over the other. Also, since the scores of each child were interpreted in relation to his/her own change in performance, this potential weakness was not considered to be a limitation in this research design.

Selection of Subtests

The BOT-2 is made up of a number of subtests that reflect categories of movement variables. Previous research has used both the long-form and the short-form of the test as well as individual subtests instead of the complete long-form (Düger *et al.*, 1999). While it is recognised that the BOT-2 has disadvantages, it is still an appealing test to use as it is relatively easy to administer and results can be compared to previous research that have used it as the assessment instrument. Each subtest includes a number of test items. Although the number of trials in many of the items is limited, the point score for each subtest is made up of the scores on all the items. This provides a relatively comprehensive look at the variable. For this study, bilateral coordination, balance and upper-limb coordination subtests of the BOT-2 were identified as the dependant variables.

The subtests for these three dependent variables (bilateral coordination, balance and upper-limb coordination) were chosen because these variables have been found to be common problems areas for children with movement coordination problems (Williams & Woollacott, 1997) and have frequently been identified as variables in research studies involving rhythmic entrainment (Bartscherer & Dole, 2005; Jacokes, 2004; Shaffer *et al.*, 2001; Zachopoulou *et al.,*2004; Zachopoulou & Mantis, 2001; Derri *et al.*, 2001a). From this the researcher deduced that these variables may be susceptible to improvement through participation in a rhythmic entrainment programme.

Training of Assistants

Five post-graduate assistants with previous experience working with children were trained to assist in the administration of the BOT-2 subtests. A training session was conducted in which the specific testing instructions as set out by the BOT-2 were reviewed. The assistants then practiced administration of the subtests on each other. A closing discussion was conducted to clarify any uncertainties.

Selection of an Intervention Instrument

Some intervention programmes have been based on the practice of specific motor skills with which children struggle, while other intervention programme try to address the underlying factors of coordination in order to impact on the performance of a wider range of skills (Parker & Larkin, 2003). A rhythmic entrainment programme is one approach to addressing timing/rhythm as an underlying factor of coordination difficulties. As described in Chapter Two, rhythm can be introduced into a movement activity in the form of a beat pattern. The beat pattern has the potential to provide an external source of structure as auditory cues help individuals whose internal timing structure may not be optimal. This use of a beat pattern is intended to contribute to the rhythmic entrainment of the movements practiced.

The instrument for rhythmic entrainment in this study was a computer-based programme called Interactive Metronome (IM) (Interactive Metronome, 2007) which produces an auditory isochronous beat, as well as concurrent auditory feedback in the form of immediate sounds that act as “guide sounds” indicating the accuracy of the response of an action to the rhythmic beat.

Interactive Training

During movement performance all sensory information that is available to an individual provides feedback about the movement that the person has produced (Shumway-Cook & Woollacott, 2007). This information is divided into two classes, intrinsic feedback and extrinsic feedback.

1. Intrinsic feedback is feedback that the performer experiences through the sensory systems as a result of the movement. Examples of this include, proprioception which provides information about the position of the limbs in space, tactile information about the feel of the movement, visual information relating to the accuracy of the movement or the product of the movement (Shumway-Cook & Woollacott, 2007).

2. Extrinsic feedback is feedback provided by an external source that supplements the intrinsic feedback. Extrinsic feedback can be given during (concurrent feedback) or at the end (terminal feedback) of a movement (Shumway-Cook & Woollacott, 2007).

Intrinsic feedback is always present to the individual (depending on the functioning of the sensory systems). Therefore, training programmes focus on the manipulation of extrinsic feedback to affect motor learning and motor development. Research has consistently indicated that an external focus of attention where the individuals focus on the effect of the movement, rather than the movement itself (internal focus) leads to enhanced motor learning (Wulf *et al.*, 2002; Shea & Wulf, 1999). The benefits of using external focus cues (instead of internal focus cues) have been shown to be effective for learning a variety of tasks (Wulf, 2007; Shea & Wulf, 1999).

Shea and Wulf (1999) hypothesised that it may be more beneficial for learning when concurrent external feedback is provided during a movement task along with an external focus of attention. They explained that concurrent external feedback serves as a constant reminder to maintain focus on task performance. External feedback also serves as a “distraction” from internal focus on the body as it moves. The study completed by Shea and Wulf (1999) specifically demonstrated that in a balance task, the strategy of concurrent feedback with an external focus of attention was more effective than concurrent feedback with an internal focus of attention. The improvements in balance scores were still present on the retention test, which suggested that the external focus/concurrent feedback strategy had a lasting effect. The authors identified two advantages of this strategy. Firstly, the concurrent external feedback enhanced performance during practise, and secondly the positive effects were not restricted to practise performance, but also in the retention test where the feedback was no longer present. This strategy has been demonstrated to enhance the learning of other tasks (Wulf, 2007). Due to this the IM, which provides external auditory feedback on the accuracy of the movement performed, could potentially enhance timing and rhythm.

Interactive Metronome

The IM programme functions in the following manner (Interactive Metronome, 2007):

1. The individual wears a set of headphones through which he/she hears the metronome beat (reference tone) as well as receives auditory feedback (guide sounds) about the accuracy of his/her performance of a repetitive movement activity to a pre-set beat.

    a) The purpose of the guide sounds is to help the individual improve the timing accuracy of the performance by giving concurrent auditory feedback about whether he/she has performed an action too early, too late or precisely on the beat.

    b) The guide sounds are the key to metronome training as they provide the interactive aspect of the programme. The individual can adjust his/her performance continuously during the duration of the practice activity in order to bring his/her performance closer to precision with the reference tone (beat pattern).

2. The individual attempts to synchronise repetitive motor movements either with his/her hands or feet, in time with the reference tone which is an isochronous beat.

a) When performing movements with the hands a pressure sensitive glove is worn that is activated when the sensor in the glove is tapped.

b) The foot movements require the individual to tap a pressure sensitive footpad that is placed on the floor.

c) The sensors in the glove and on the footpad are attached to a control box. The control box is connected to a computer which is runs the programme that can detect the activation of the sensors. The programme records the accuracy of each movement in relation to the reference tone (how early, how late, or if the movement was on the beat). This record is stored as data on the computer for future analysis.

d) An individual's score (average ms off-the-beat) for each of the tasks can be calculated by the programme. Age norms have been published by the manufacturer so that an individual's results can be compared to age norms if that is desired (see Figure 17 in Appendix A).

e) The tempo of the beat can be adjusted but the manufacturer recommends using a tempo of 54 beats per minute.

f) The guide sounds can be switched on or off and the volume of each sound can be adjusted if desired.

3. There are three guide sounds and they are delivered in three different ways (see Figure 3).

a) If an individual performs to the beat within15 milliseconds (early or late), they will hear in both ears simultaneously, a high pitched 'toot' which signals that they are on the beat.

b) If an individual performs slightly too early or too late to the beat, a rubber 'tang' is heard which means he/she is performing either slightly too fast or slightly too slow.

- If this sound is heard in the left ear, it means that he/she is moving slightly too fast and performing before the beat, and the tempo of the performance needs to be decreased.

- If this sound is heard in the right ear, it means that he/she is moving slightly too slowly and performing after the beat, and the tempo of the performance needs to be increased.

c) If an individual performs far off the beat, whether too early or too late, a ‘buzz’ is heard which is an indication of moving “way too fast” or “way too slow.”
   - If this sound is heard in the left ear, it means that he/she is moving too fast and performing far before the beat and the tempo of the performance needs a major adjustment.
   - If the sound is heard in the right hear, it means that he/she is moving too slowly and performing far after the beat, and the tempo of the performance needs a major adjustment.

Situation	***Hits before beat***		**On the beat**	***Hits after beat***	
Outcome	***Sound in left ear***		**Sound in both ears**	***Sound in right ear***	
Feedback	***Way too fast***	***Too fast***	**Super right on**	***Too slow***	***Way too slow***
Sound	***Buzz***	***Tang***	**Toot**	***Tang***	***Buzz***
Meaning	***Acting very early***	***Acting early***	**Acting on time**	***Acting late***	***Acting very Late***
Difficulty range (can be pre-set by certified provider)					
Level 100	-101 to 555 ms	-16 to 100 ms	0 to +/-15 ms	16 to 100 ms	101 to 555 ms
Level 200	-201 to 555 ms	-16 to 200 ms	0 to +/-15 ms	16 to 200 ms	201 to 555 ms
Level 300	-301 to 555 ms	-16 to 300 ms	0 to +/-15 ms	16 to 300 ms	301 to 555 ms

Figure 3. A visual representation of the guide sounds and what they mean.

4. The level of difficulty for adherence to the beat pattern can be manipulated by changing the difficulty setting (Level 100, Level 200 or Level 300). This changes the range (in milliseconds) of acceptability in deviation from the beat pattern which results in a change in when the individual hears the different guide sounds (Figure 3).
5. Three different approaches or training modes can be offered to an individual. These include a Long Form Assessment mode (LFA), a Short Form Test mode (SFT) and a Regular Training mode (RT):
   a) The LFA is a 14-task sequence of movement activities that takes 20-30 minutes to perform. It can be used either as the content for a practice session or at key points during an intervention programme to assess an individual's progress in terms of rhythmic entrainment.
      - LFA assesses upper and lower limbs individually and also include bilateral and balance tasks. Descriptions of these tasks can be found in Figure 16 in Appendix A.
      - The LFA has the following default settings:

- Tempo: 54 beat per minute.
- Duration: 30 to 60 seconds per task.
- Difficulty setting: Level 100.
- Guide sounds are off for all the tasks except task 14.

b) The SFT is a two-minute evaluative tool which consists of two tasks. The SFT is advised to be administered at the beginning and/or the end of a session. This monitors the individual's progress from one session to the next.

- Task 1 requires the individual to clap both hands together in time with the beat for one minute. Task 1 of the SFT is the same as task 1 of the LFA.
- Task 2 is the same as task 1 except the guide sounds are heard. Task 2 in the SFT is the same as task 14 in the LFA.
- The SFT has the following default settings:
    - Tempo: 54 beats per minute.
    - Duration: 60 seconds.
    - Difficulty setting: Level 100.

c) The RT mode is used during IM training sessions. The movement activities available in this mode are the same as those described for the LFA in Appendix A (Figure 16), but their delivery is not pre-programmed. A certified provider can manipulate the delivery of the activities, for example, changing the volume of the guide sounds (the researcher in this study was a certified provider).

Training of the Researcher

The researcher completed a formal certification course to become a registered IM programme provider. This course required the completion a 12 module self-study course that included both theoretical and practical work. It was necessary to satisfactorily pass all the assessment tasks that were completed throughout the course. These tasks were emailed to Interactive Metronome, Inc., who controls the registration process for providers. An online final examination was successfully passed in order to complete the certification process. The following competencies describe the capabilities of a certified IM programme provider (Interactive Metronome, 2007):

1. Cite specific research studies related to IM training.
2. Provide evidence-based practise to clients.
3. Implement LFA and SFT assessments and interpret results in order to design individualised intervention programmes.
4. Demonstrate proficiency in adjusting IM settings in order to meet the unique needs of individual clients.
5. Formulate and interpret reports for clients.

Selection of Participants

Prior to the commencement of the study the principal and the teachers of a local primary school were asked if they would be willing to assist with the implementation of this research project. Following their expression of interest, formal permission was requested and granted by the Western Cape Education Department and Ethics Committee of Stellenbosch University.

The teachers were asked to observe their classes playing during recess time and to identify children who appeared to have poor motor skills compared to their peers. An information sheet and informed consent (see Appendices B and C) were given to the headmaster, who indicated that a shortened version also should be sent to the parents (see Appendix D). All parents returned signed permission forms and then the children were each asked by their teachers if they wanted to participate. They all said that they did.

Baseline Assessment

Twenty-two children voluntarily completed the selected subtests of the BOT-2. The scores of these subtests were analysed according to standard scores. There was a “natural break” in the results and the eight children who scored the lowest when compared to the other children were identified as participants in this research. Their age ranged from 9 to 12 years old (mean age 11). The group consisted of seven boys and one girl. None of the children had any noticeable problems.

The school hall was used as the testing venue. For each of the testing sessions the same protocol was followed. The testing area was prepared prior to the children's arrival. The children were met at their classrooms and brought to the hall. Before testing began, the children were introduced to the assistants and were told about what they were going to do. They were also asked to try their best when they performed each subtest. The children were then randomly assigned to small groups (two to three individuals) and then rotated around the hall until they had all completed all the activities. At each station the group of children were given a demonstration of what they were going to do on the subtest. Then while one child was busy, the others sat and waited their turn. The instructions were then given again to make sure that each child understood the subtest. The testing procedure as set out by the BOT-2 was followed carefully, and each child was scored accordingly to BOT-2 specifications. See Appendix D for the scores sheets. At the end of the testing session the children were thanked for their time and effort and taken back to their classroom.

Pre-test

The identical testing protocol followed for the baseline assessment was followed for the pre-test session four weeks later.

Intervention Programme

The metronome-based training programme consisted of 11 sessions over a period of three weeks. The children were assigned different time slots every day. Each child came individually to the training sessions. Although the training was presented individually, the movement activities were the same for all participants. A picture of a child ready for participation in an IM training session is presented in Appendix E, which illustrates the IM set-up.

- The goal of the training programme was for the child to perform pre-designed repetitive movement activities in time to a metronome beat. The beat was set at a tempo of 54 repetitions per minute.

- Each session was approximately 30 minutes long, however, a session usually consisted of only ±15 minutes of active training time. The beginning was focused on getting ready for training.

- The LFA sequence of movements was completed in session one and again in the last session (session 11) of the training programme. Each child’s performance of the initial LFA sequence provided information about the precision of his/her entrainment of the movements in the sequence as well as served as a familiarisation with the IM equipment and all of the different tasks that would be practiced later in the programme. Each child’s performance of the LFA sequence during the last training session served to provide the researcher with an indication about the progress of the child in terms of his/her entrainment of the movements in the sequence.

- The SFT was performed at the beginning of sessions two through 10. It was presented immediately following the warm-up. The results of the SFT were used by the researcher to monitor each child’s progress from one session to the next.

Examples of the movement activities presented in an IM training session are presented in Appendix F (Figure 16). See Appendix G for complete IM training programme details.

The Intervention Sessions

All the sessions began with a warm-up of 10 claps to the beat. Before the child performed an activity, the researcher first showed the child what was expected of them. They then performed the exercise together. The child was then asked to perform two to three repetitions of the activity on their own so that the researcher could ascertain whether he/she knew what they were required to do. If he/she did not get it right the procedure was then repeated. Some of the children struggled with the concept of slow and fast, and hard and soft. Therefore in the first three training sessions (sessions two to four) the researcher spent time clapping slow and fast, and soft and hard before the training began. If the child went off-beat during the performance of the activity the researcher began to perform the movement on time, so that the child returned to the synchronous state. If this did not help, the researcher used hand-over-hand physical guidance as assistance.

The child was instructed to listen to the first three beats before beginning the movement activity, and then to make smooth controlled movements to the timing of the beat pattern. When the guide sounds were switched on the researcher explained the meaning of these sounds to each child. The guide sounds were introduced to the child in his/her first session, with the following instructions:

- A ‘buzz’ or rubber ‘tang’ in the left ear meant slow down in order to move in time to the beat.
- A ‘buzz’ or rubber ‘tang’ in the right ear meant speed up to move in time to the beat.
- A ‘toot’ heard in both ears meant that the movement was in time to the beat.

Once the child appeared to be reacting correctly to the ear in which the sounds were made, the following additional instructions were provided:

- A ‘buzz’ in the left ear meant to go a lot slower, and a ‘buzz’ in the right ear meant to go a lot faster in order to move in time to the beat.
- A ‘tang’ in the left ear meant to go a just a bit slower, and a ‘tang’ in the right ear meant to go just a bit faster in order to move in time to the beat.

When explaining how the different sounds in the left and the right ears had different meaning, the researcher gently touched the left or right ear of the child, so that had an additional cue to call their attention to the ear in which they were hearing the sound. At the beginning of each session, and sometimes during the session, the researcher asked a child to tell her what was supposed to happen when the different sounds were heard. The children were also periodically asked what on what kind of sound they were using as the beat pattern, in order to make sure they were focused on the beat. In addition to the above, the following additional forms of support were provided:

- If any child appeared to forget or become confused by the different sounds, the researcher verbally cued him/her to either slow down or speed up depending on the guide sounds. This support was always provided when a child was constantly hearing the very early or very late buzzer.
- For the activities that required standing and potentially a challenge to balance, a chair was placed next to the child within reaching distance. The children were told that they should hold onto the chair for support only if they felt they were going to lose their balance. Toward the end of training programme, those who were using the chair were encouraged to only use one finger to hold or touch if they needed help in keeping their balance.

Post-test

The identical testing protocol followed for the baseline assessment was followed for the post-test session eight weeks later.

Retention Test

The identical testing protocol followed for the baseline assessment was followed for the retention test 12 weeks later.

Data Analysis

The data was analysed on a group basis, as well as a case-by-case basis. The group data was analysed by the Centre for Statistical Consultation at the University of Stellenbosch. Statistica 8.0 (Statsoft, Inc.) was used to analyse the data. Group data was analysed using the ANOVA for dependent groups. Changes in motor performance were considered statistically significant at $p \leq 0.05$.

For the individual cases the raw scores that were recorded for each item of the subtest were added to produce a total point score for each of the subtests. The point scores were then converted to scale scores using the tables provided by the BOT-2. The scale scores are presented graphically so that the improvement could be tracked. The point scores were also presented.

Post-intervention Workshop

Once the research period had ended, the researcher conducted a mini-workshop with all the teachers at the school to share with them the basics of movement and rhythm education. The teachers were shown how they could implement rhythmic activities during physical activity lessons that required very little equipment and space. This was done so that all the children at the school could potentially benefit from participation in rhythmic movement activities. A copy of the mini-workshop manual can be found in Appendix H.

Summary

This study followed an A-B-A reversal design. The experimental group was composed of eight children between the ages of 9 and 12. The group consisted of seven boys and one girl.

Three subtests, bilateral coordination, balance and upper-limb coordination, of the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) were used to assess the children's gross motor abilities. Testing took place four times over the period of the study. The first test was conducted to establish baseline data as well as to identify the children who had the poorest scores who then formed the experimental group. This baseline test was then followed by a control period of three weeks where no intervention took place. A second test was conducted pre-intervention, and a third test conducted post-intervention. A fourth test was conducted three weeks (no intervention took place) after the third test to determine whether any improvements in the BOT-2 were retained.

The intervention consisted of a metronome-based training programme that consisted of 11 sessions over a period of three weeks. Each child came individually to the training sessions. Each session was approximately 30 minutes in length, however the sessions consisted of between 10 to 15 minutes of active training time. The training programme required the child to perform pre-determined rhythmic movements in time to a beat.

Group data was analysed using the ANOVA for dependent groups. Changes in motor performance were considered statistically significant at $p \leq 0.05$. The individual data was also analysed descriptively on a case-by-case basis.

Chapter Four

Results and Discussion

The following chapter presents the results produced by the participants during the course of this research. The results for the group and relevant discussion for each of the three dependent variables (bilateral coordination, balance and upper-limb coordination) are presented first. The effects of the programme on three individual children are then reported and discussed in order to illustrate the individual variability among children described as displaying delays in motor development.

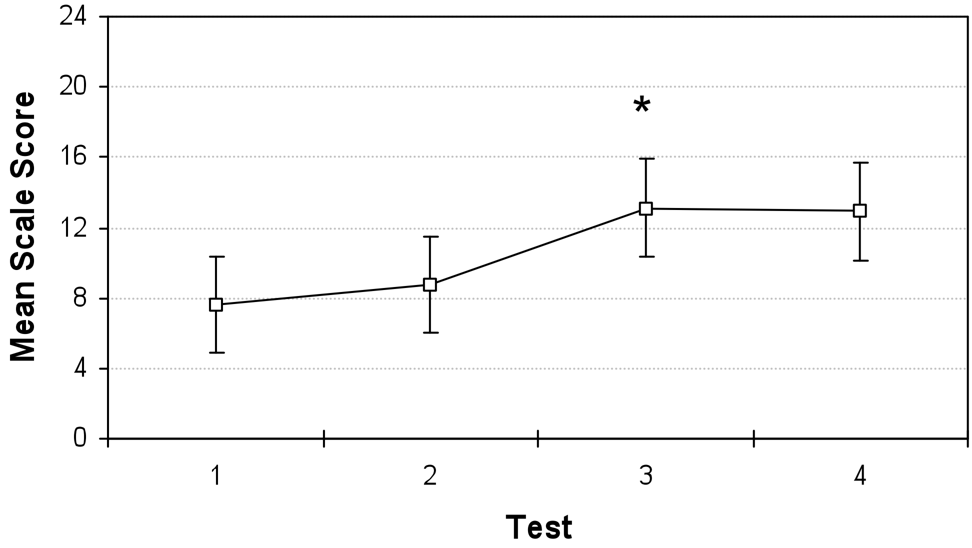
The group of participants consisted of eight children (seven boys and one girl) between the ages of 9 and 12, with a mean age of 11 years and 5 months. Error bars indicate 95% confidence intervals. Due to the heterogeneous the error bars appear to be relatively large. For the baseline test, pre-test and post-test, n=8 while for the retention test, n=7 as one of the child was absent from school for the entire week available for testing.

Bilateral Coordination

1. What are the effects of participation in a metronome-based training programme on the bilateral coordination of children who appear to have motor development delays?

There was a significant improvement in the mean bilateral coordination scores of the group after participation in the rhythmic training programme ($F_{3, 20}$ = 13.299, ρ = *0.00005).* Between the baseline test and the pre-test results and between the post-test and the retention test results, there were no significant changes in the bilateral coordination. See Figure 4.

The small improvement seen between the baseline and the pre-test scores may show a small learning or familiarisation effect on the test, although if this is the case, it is only very slight. The significant difference was found between the pre-test and the post-tests, which is an indication that the intervention programme did have an effect on bilateral coordination as measured by the BOT-2. It can be noted that this improvement was retained after a three-week period.



* ρ < 0.05: Between time 3 and time 2

Figure 4. The mean bilateral coordination scale scores of the group for each of the four test sessions (Mean ± 95% confidence intervals).

During the rhythmic training sessions, many of the children initially struggled with bilateral coordination tasks. However their performances on these tasks improved throughout the training sessions. This significant improvement in the bilateral coordination BOT-2 subtest scores indicates that the improvement in bilateral coordination during the training was generalised at least to the BOT-2 subtest items that requires bilateral coordination. This indicates that participating in a metronome-based training programme has the potential to positively affect the motor planning and sequencing involved in bilateral coordination tasks.

This result is similar to the results reported by Jacokes (2004) who also found that metronome-based training led to an improvement in bilateral coordination. The retention of improvements was also found in the Jacokes' study after both a three- and a six-month period. This indicates that the immediate improvements realised after rhythmic training may be retained over an extended period of time. A case study completed by Bartscherer and Dole (2005) produced a positive effect on the bilateral coordination of a child following participation in a metronome-based training programme. However, the positive effect was not significant, which highlights that the each individual may react somewhat differently to the intervention programme.

Balance

2. What are the effects of participation in a metronome-based training programme on the balance of children who appear to have motor development delays?

No significant improvement ($F_{3, 20} = 1.1441$, $\rho = 0.35547$) was found in balance as measured by the BOT-2 over the duration of this study (see Figure 5). As with the results of bilateral coordination testing, there is a very slight improvement between the baseline test and the pre-test that may be an outcome of test familiarisation.

Finding no significant improvement following participation in the intervention programme is contrary to the findings of Jacokes (2004) and Bartscherer and Dole (2005). They both found significant improvements when comparing the pre-test to post-test changes in the balance of children who had attention and motor coordination difficulties following participation in a metronome-based training programme. In the Jacokes (2004) study, the improvement in balance was maintained on both a three- and a six-month retention test. The results also are incompatible with the findings reported in a study by Zachopoulou *et al.* (2004). In that study, the dynamic balance of children in the experimental group improved significantly after the completion of a music and movement programme, while the children in the control group who followed a physical education programme without a rhythmic accompaniment component, did not achieve a significant improvement in their dynamic balance. The control group, even with specific balance training, showed a much smaller improvement in balance scores than the experimental group.

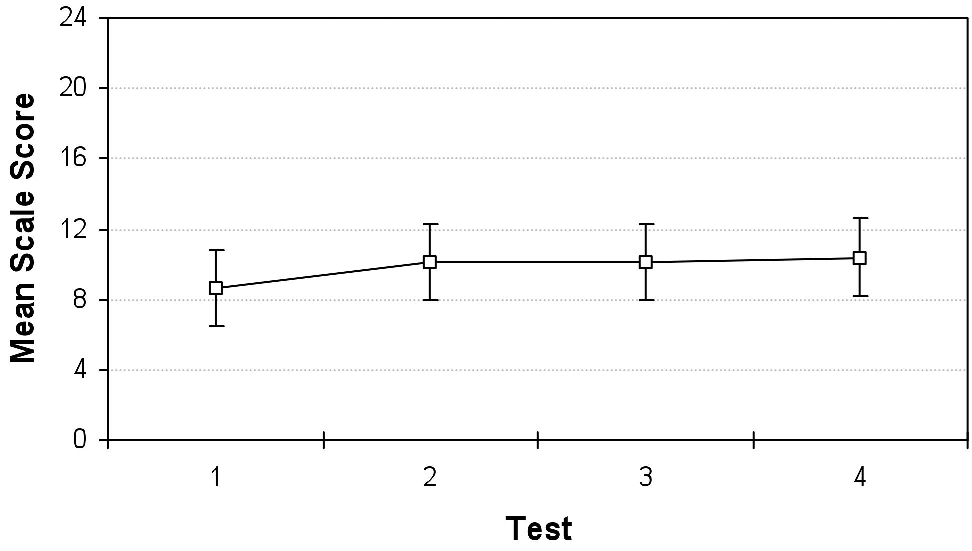


Figure 5. The mean balance scale scores of the group for each of the four test sessions (Mean ± 95% confidence intervals).

Upper-limb Coordination

3. What are the effects of participation in a metronome-based training programme on the upper-limb coordination of children who appear to have motor development delays?

Figure 6 presents an interesting curve as it illustrates a significant difference ($F_{3, 20} = 2.7728$, $\rho = 0.06814$) was achieved between the baseline test and the post-test, but not between the baseline and the pre-test or the pre-test and the post-test. It is possible that progressive familiarisation and/or learning took place between the first time the children were tested and the third time.

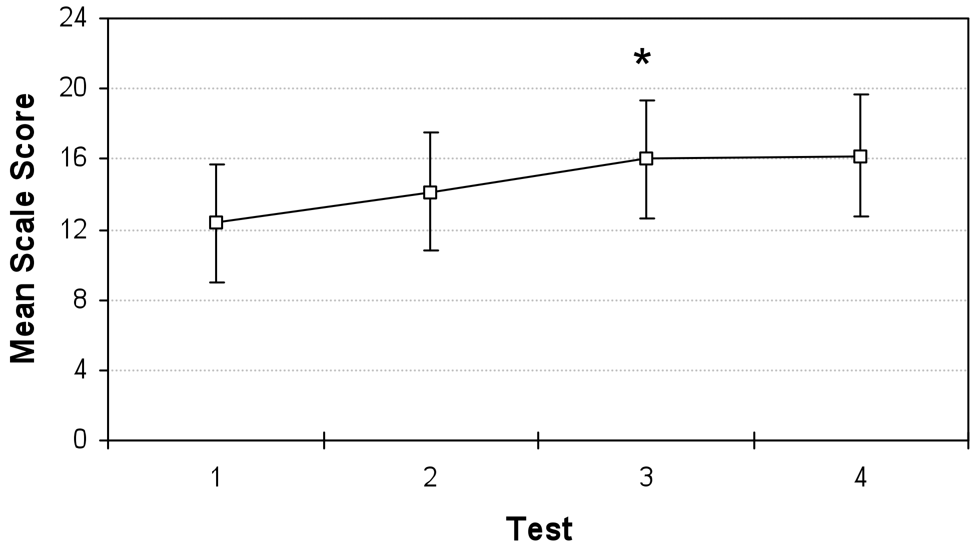


Figure 6. The mean upper-limb coordination scale scores of the group for each of the four test sessions (Mean ± 95% confidence intervals).

Although Wilson *et al*. (1995) stated that it is acceptable to re-administer the BOT-2 within a three to four week period in order to assess change, the initial scores of the children who participated in this study were relatively high, which left very little room for improvement. One drawback of the BOT-2 is that it sets a ceiling on the maximum that the individual can potentially achieve (Burton & Miller, 1998). For example, there are only five attempts on the catching item. If a child scores five out of five for a catch, it is not known how many more catches that child could have made. A test that was more discriminatory would be more sensitive to change. If learning/familiarisation did take place from the baseline test to the post-test, then a different and more reliable assessment test is needed for upper-limb coordination that will reflect a more stable scoring pattern from the baseline test to the post-test.

Previous research is equivocal about the potential of rhythmic training to improve upper-limb coordination. The study by Jacokes (2004) reported that there were no significant differences between the pre- and post-tests for upper-limb coordination after participation in metronome-based training. However, Zachopoulou and Mantis (2001) studied the effect of a general rhythmic activity training programme on tennis forehand groundstrokes of children as measured by the number of correct hits in a row. They found that the experimental group significantly improved in their performance. It may be instructive to note that the scores on their test were not capped by any set number of attempts so the children performed the maximal number of which they were capable.

Effects on Individual Children

4. What are the effects of participation in a metronome-based training programme on the bilateral coordination, balance and upper-limb coordination of individual children who display motor development delays?

Knowing that children with movement problems should be regarded as unique in terms of their potential to react positively to different interventions, motor development specialists emphasise that it is more important in research to identify which programmes are more effective for which individuals, rather that to try to identify generally effective programmes (Parker & Larkin, 2003). According to Wilson *et al.* (1995) when measuring a child's progress it is more useful to compare the child's performance scores with his/her previous scores. Although these scores may not support the calculation of statistical significance, comparison between them can give an indication of clinically important differences that allows researchers to track the direction of changes in a particular child's motor performance.

In the following section the results of three children who participated in this study are presented. A fictitious name is assigned to each child to facilitate the narrative. Individual results from the other five children who participated in this study are found in Appendix I. These results show not only how much children vary in their performances, but also how different their responses were to the intervention programme. The scale and point scores attained on the BOT-2 subtests are presented. To obtain the total point score for each subtest the raw score of each test item is given a point score. A point score is a standardised score which allows the performance of an individual to be avaluated on a graded scale. The item point scores are then added together to obtain the total point score for the particular subtest. The total point scores are then converted to a scale score using tables provided by the BOT-2. The scale score indicates the individual's level of proficiency on each subtest in relation to their age, this score can range from one to 35 (Bruininks & Bruininks, 2005). The point scores gives an indication of the individual's raw score and therefore can be useful for identifying and tracking changes (Wilson *et al.*, 1995). In addition to the BOT-2 scores the two reports generated by the software that ran the rhythmic training tasks are also presented. The computer programme recorded that accuracy (time in ms) of the child's performance, in terms of how far off from the isochronous beat generated by the metronome his or her response was.

The Short Form Test (SFT) is a report of session-by-session performance and the Long Form Assessment (LFA) is a report of 14 tasks performed during a single session. In this study, the LFA was generated during the pre-test session and the post-test session. The measurements of time deviations from the beat established by the metronome were not outcome measurements in this study because moving to the beat set by the metronome was the premise of the movement tasks upon which the intervention programme was based. For example, it was anticipated that the initial scores achieved on the pre-LFA would be affected by the children's inexperience in performing to a metronome beat, as well as the unfamiliar training medium (wearing headphones while responding to instructions provided by a computer programme). However, tracking the pattern of their performance may provide a picture of the emergence of their entrainment of the coordinative structures called for by the tasks. One would expect a reduction in the time of deviation from the beat pattern if the children were either becoming more comfortable with how to perform as instructed, or if they were actually improving in terms of entrainment.

Case 2: Joseph

Joseph appeared gangly, clumsy, uncoordinated to the point that his movements appeared almost spastic during the baseline period and for the first few sessions of the intervention programme. He had very poor balance, which was reflected in his low BOT-2 scores (see Figure 7). For the tasks focused on balance (tasks 12 and 13) during the intervention, he had to initially support himself by holding onto the back of a chair for the full 30 seconds. However, through the course of the training he was encouraged to hold on with fewer fingers until finally he was not holding on anymore even though the chair was still there. His balance score on the pre-test was lower than on the baseline test, which may be an indication of the variability of his balance control. The steady slope of improvement from pre-test to post-test illustrates positive changes, but the continued improvement through to the retention tests again reinforces the variability of Joseph’s balance control.

During the intervention programme, the simple upper-limb coordination task of clapping his hands and moving his hands in outward circular motions was a challenge. He would start by doing outward circular motions and then spontaneously move into inward circular motions. The movements ranged from large to small. When the researcher provided hand-over-hand assistance, it was almost as though his arms fought to go in the wrong direction even though he understood what he was supposed to do, and he was trying his best to do so.

The lower-limb tasks of the intervention (tasks 4 to 13) were also extremely challenging especially those that required bilateral coordination (tasks 10 and 11). Prior to performing these tasks Joseph would practice them with the researcher without hearing the beat, and then the beat would be introduced and he would try to coordinate his performance to the beat pattern. However, after completion of the training programme, he could perform all the tasks smoothly, required no assistance and showed no signs of spontaneous spastic movements.

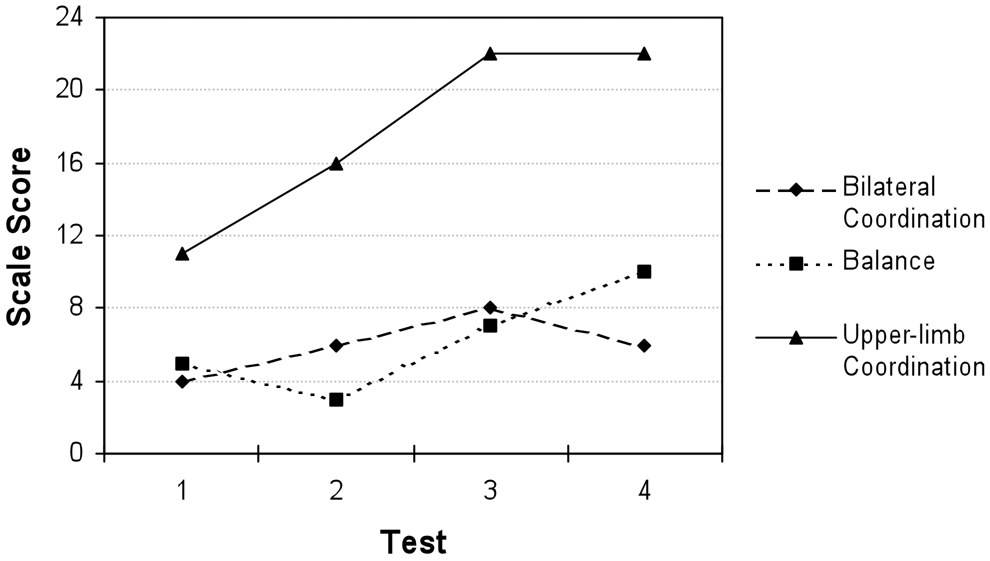


Figure 7. The scale scores reported for Joseph on each of the three BOT-2 subtests.

Table 1
Joseph's scores on the each of the subtests for each test session in relation to the maximum points possible on each subtest

Subtest	**Total Points Possible**	**Point Scores**			
		Baseline Test 1	Pre-test Test 2	Post-test Test 3	Retention Test 4
Bilateral Coordination	*24*	5	10	17	13
Balance	*37*	21	13	27	30
Upper-limb Coordination	*39*	34	37	39	39

Joseph showed improvements from the baseline to the post-test performance of the BOT-2 subtest of upper-limb coordination which suggests that he experienced a learning effect (see Figure 7), however he reached maximal points after the intervention period, and this was maintained in the retention test (see Table 1). Looking at the post-test bilateral coordination point score (see Table 1), it appears that there was a great improvement in Joseph's bilateral coordination following participation in the intervention programme. However, according to his performance on the retention test, that improvement was lost somewhat once the programme was stopped. The change in Joseph’s performance between the baseline test and the pre-test may indicate his lack of experience or adaptability of his movement performance to new environments. His scores did not approach the maximum score possible on this test, which could support the recommendation that he would probably benefit from a longer training programme where more experience is provided. The same could also be said for Joseph’s balance. His comparatively low score on the pre-test following a better performance on the baseline test suggests that his balance control was inconsistent at the beginning of the programme. His balance scores were not very close to maximum points possible. His upper-limb coordination scores achieved maximum levels on both the post-test and the retention test. This supports the use of three different tests in this study, since it appears a child can be strong on one variable but less strong on another.

A look at the results of the SFT shows that Joseph performed relatively the same in terms of average ms off the beat during each practice session, with or without guide sounds (see Figure 8). This indicated that his auditory discrimination of the beat was very good, and he that was able to use the guide sounds to clap on the beat. Considering his relatively low BOT-2 scores on bilateral coordination and balance, he performed well on the SFT. This may have been a function of his upper-limb coordination, which earned high scores on the BOT-2. His performance was generally consistent over the nine sessions according to the SFT, although there were days, especially day eight, when his rhythm appeared to be very “off”.

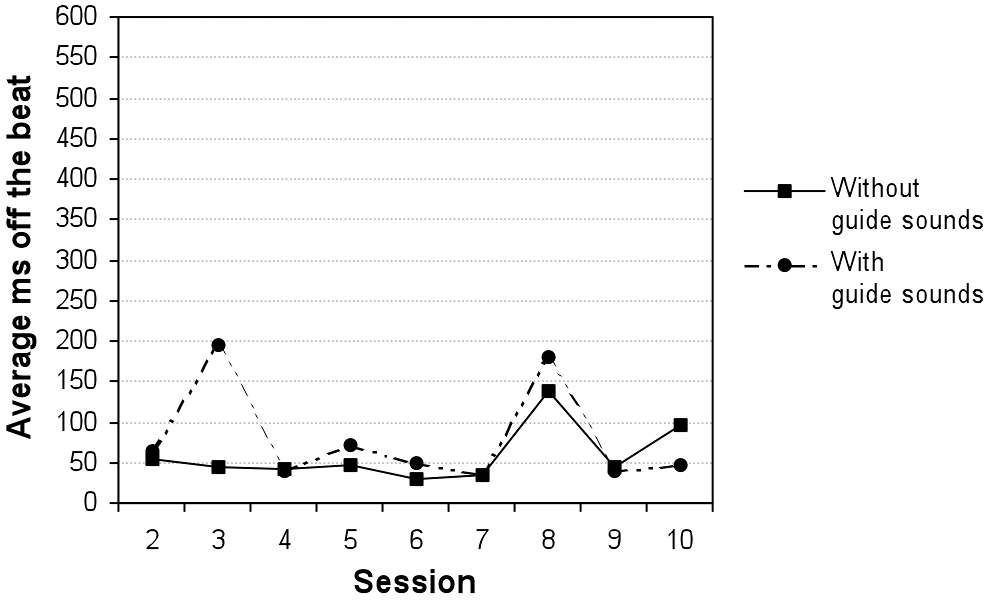


Figure 8. Joseph's SFT results over the 10 sessions of the intervention programme.

Figure 9 illustrates Joseph's LFA pre-test compared to his post-test performance of 14 tasks. His results showed poor performance in timing and coordination of his lower limbs (tasks 4 to13) and bilateral tasks (10 and 11) on the pre-test and his ratings according to the manufacturer's manual (Interactive Metronome, 2007) ranged from "below average" to "extremely deficient". However, after the intervention programme, his post-test scores showed a dramatic improvement along with the improvement in the smooth rhythmic tapping. The lower limbs (tasks 5 to 13), bilateral (tasks 10 and 11) and balance (tasks 12 and 13) tasks especially show his improvement where most of the scores are below 100 ms off the beat, with his upper-limb tasks (1, 2, 3 and 14) reaching below 30 ms off the beat which puts him in the "exceptional" category. The only task he did not improve on was task 4.

The improvements in the bilateral tasks are consistent with his improvement in the bilateral coordination scores of the BOT-2, which suggests that perhaps by actively engaging in bilateral activities, his bilateral coordination improved. This improvement could have been achieved without participation in a rhythmic entrainment programme. Research by Derri *et al.* (2001a) and Zachopoulou *et al.* (2004) did find that greater improvements were observed when rhythmic entrainment techniques were combined with traditional approaches to skill learning.

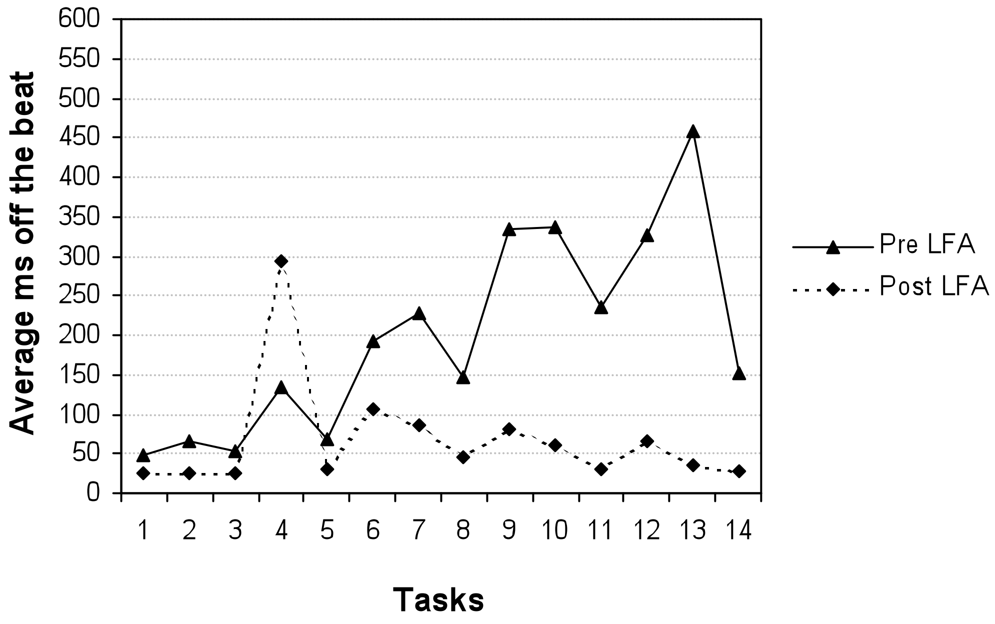


Figure 9. Joseph's pre- and post-test performance on each task of the LFA.

The effects on Joseph can be summarised as:

- Improvement in bilateral coordination, balance and upper-limb coordination.
- Improvement in bilateral coordination not fully maintained after retention period.
- Improvement in rhythmic timing post-intervention.
- Movements appeared to be smoother and controlled after the intervention.

Case 5: Carl

Carl was extremely shy, reserved and unsure of himself, but with a lot of encouragement he started to come out of his shell. He really struggled to listen to the metronome beat throughout the programme. Although he seemed to understand the purpose of the guide sounds, he did not seem able to use them to improve his performance. He would clap on time for a few beats then go way-off the rhythmic beat. He also had difficulty consistently identifying and responding to cues relating to his left and right side of the body. The concepts of hard versus fast and slow versus soft also appeared to be confusing to him. He often confused slow movements with soft movements. Prior to putting on the headphones for the training the researcher would do slow and fast clapping with him, mixing up hard with soft clapping to try to teach him the differences. He also required a lot of hand-over-hand as well as visual cues to support training where the researcher would also clap or tap in time with the rhythm and he would watch and copy her movements at the same time.

Carl achieved an improvement in his bilateral coordination, balance and upper-limb coordination following participation in the intervention programme (see Figure 10). His performances continued to improve or remain the same after the retention period. His improvements in the bilateral coordination subtest suggest that the rhythmic tasks in the intervention programme may have been beneficial for him. His score for upper-limb coordination was initially high in terms of his point score (see Table 2), but still did show a slight improvement on the post-test and retention test. The smallest improvement was recorded for his balance, and no change was registered between his post-test and retention test performances.

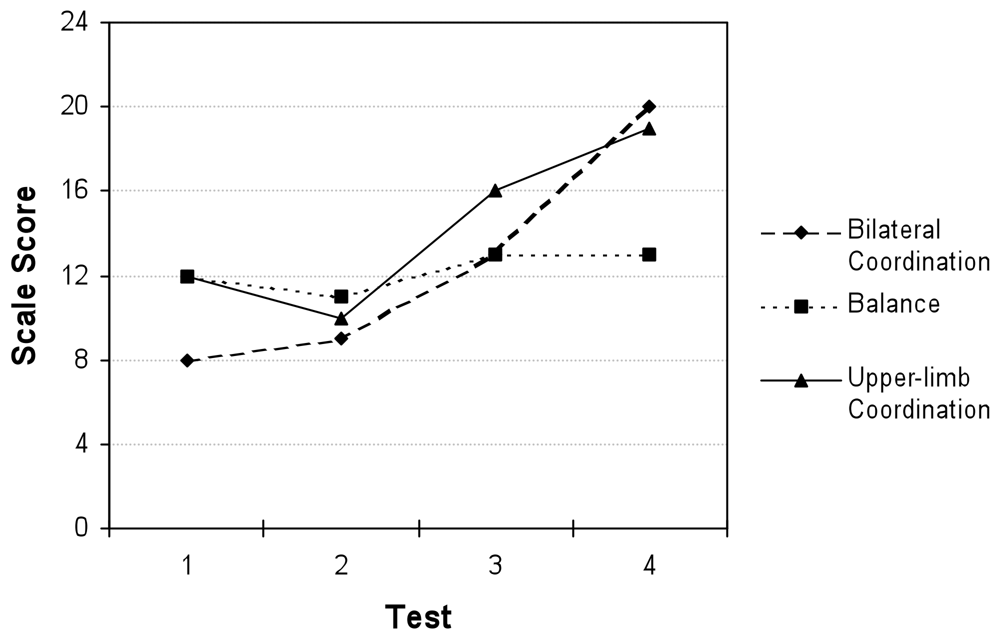


Figure 10. The scale scores reported for Carl on each of the three BOT-2 subtests.

Table 2

Carl's scores on the each of the subtests for each test session in relation to the maximum points possible on each subtest

Subtest	**Total Points Possible**	**Point Scores**			
		Baseline Test 1	Pre-test Test 2	Post-test Test 3	Retention Test 4
Bilateral Coordination	*24*	18	19	22	24
Balance	*37*	32	31	33	33
Upper-limb Coordination	*39*	35	33	37	38

Figure 11 illustrates Carl's performance of the SFT for each session. It can be noticed that he struggled using the guide sounds when compared to performing the task without guide sounds. Throughout the training programme his rhythmic timing without the guide sounds was better than with the guide sounds. His scores for ms off the beat without guide sounds became more consistent and fell within the “average” rating category throughout the training period.

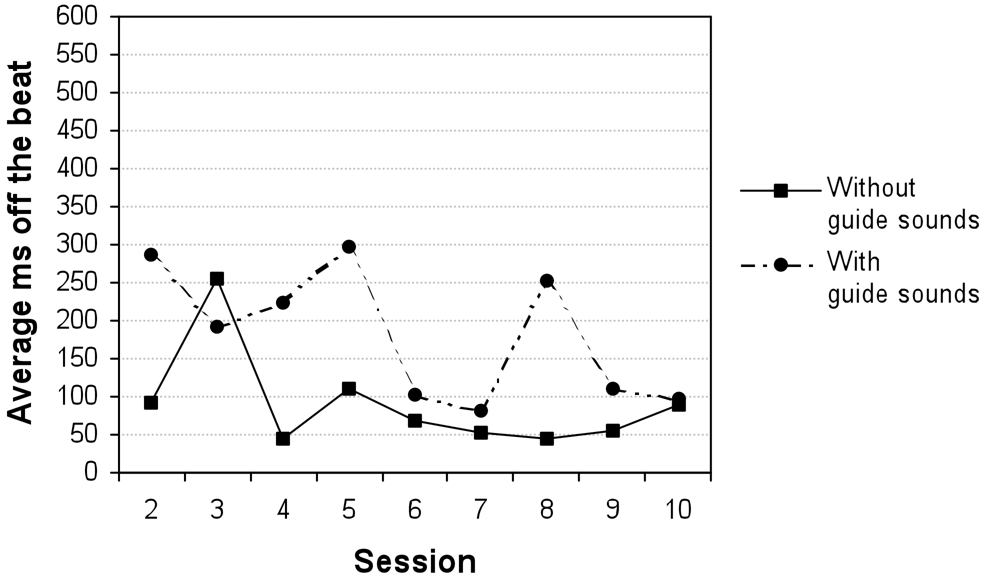


Figure 11. Carl’s SFT results over the 10 sessions of the intervention programme.

Carl’s pre-test LFA scores revealed that both his lower-limb and upper-limb performances were poor. His upper-limb performance scores (tasks 1, 2, 3 and 14) did show improvement on the LFA post-test (see Figure 12). He also achieved improved timing on tasks 4, 6, 7 and 10, and especially task 8. Tasks 8 and 9 involved the tapping the footpad with the right and left heel respectively. He actually performed worse on the post-test for tasks 5, 11, 12 and 13. His scores for these tasks remained in the “below average” to “extreme deficiency” range despite participation in the metronome-based training programme.

Although Carl achieved very little overall improvement in his LFA scores, there was a slight improvement in his performance on the BOT-2. His improvement in the upper-limb tasks on the LFA may have contributed to improvements in his upper-limb coordination score as measured by the BOT-2.

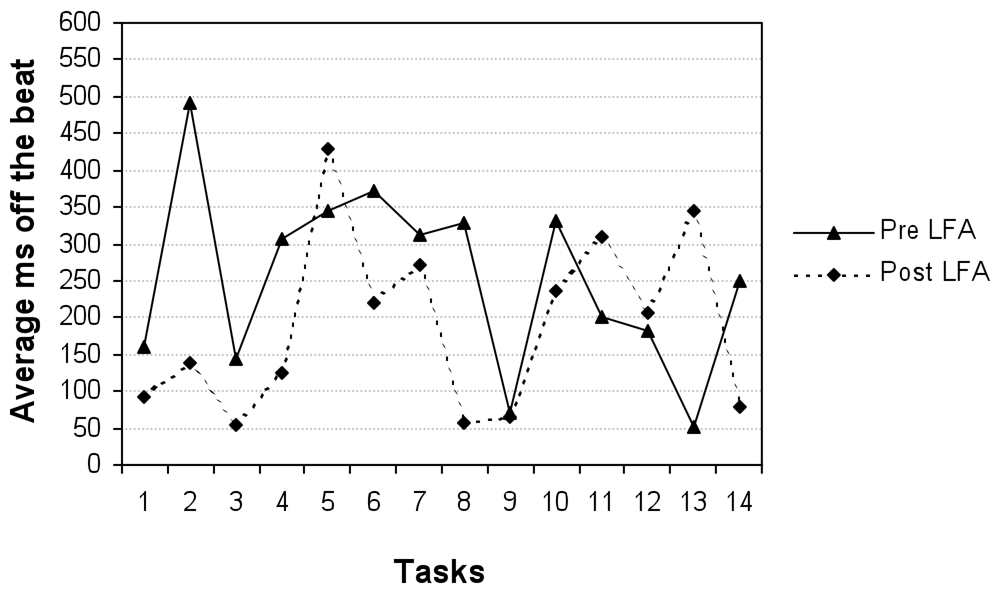


Figure 12. Carl's pre- and post-test performance on each task of the LFA.

The effects on Carl can be summarised as:

- Small improvements in BOT-2 subtests.
- Some tasks improved in LFA.
- Rhythmic timing performance remained relatively poor after intervention.

Case 8: Tom

In the initial intervention sessions, Tom displayed associated movements with his one hand while performing a task with the other hand or limb. The researcher either held the non-performing hand, or had Tom put that hand in his pocket to remind him not to move it. His control over these associated movements improved over the training period. It was several sessions before he fully understood the use of the guide sounds as feedback on his performance, but once he understood he made progressive improvement in his timing. His concentration and focus during the training sessions also improved over the duration of the programme.

Tom’s bilateral coordination appeared to improve following participation in the training programme, but this improvement was not maintained on the retention test. This suggests that he was able to improve but needed a longer training period with bilateral coordination as a priority to lead to a more permanent improvement.

He maintained his balance scores from the baseline testing through to the retention test, indicating that participation in the programme did not have much of an impact on his balance. However when looking at the point scores (see Table 3), it can be seen that his scores on the balance subtest were high for each of the four assessments. In other words, his balance was good before he entered the programme so a large change could not be expected.

His upper-limb coordination was good to begin with, and remained consistent over the testing periods. The substantial increase in the upper-limb coordination scale score between the post-test and the retention test is due to him scoring maximal points in the retention tests (see Table 3).

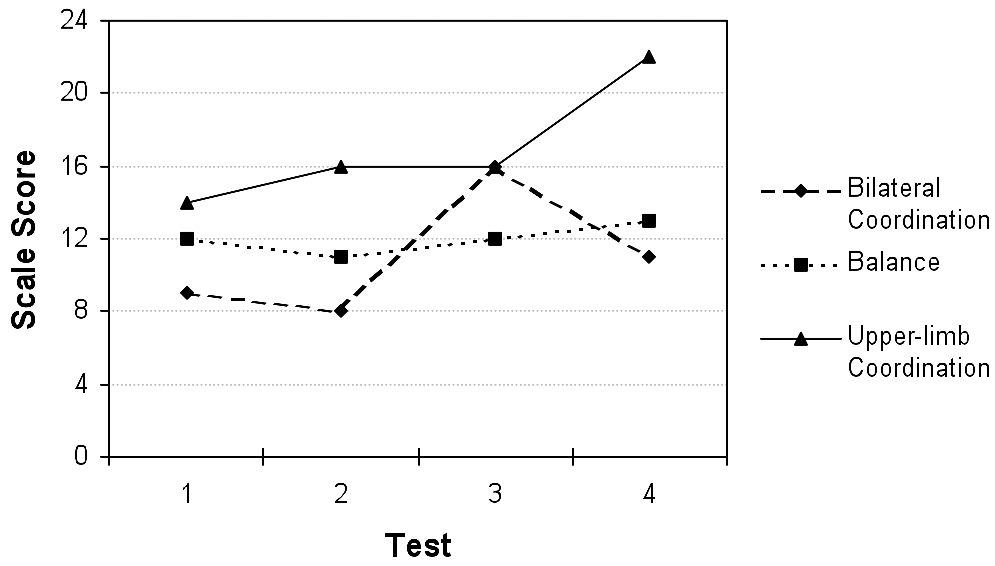


Figure 13. The scale scores reported for Tom on each of the three BOT-2 subtests.

Table 3

Tom's scores on the each of the subtests for each test session in relation to the maximum points possible on each subtest

Subtest	**Total Points Possible**	**Point Scores**			
		Baseline Test 1	Pre-test Test 2	Post-test Test 3	Retention Test 4
Bilateral Coordination	*24*	18	17	23	21
Balance	*37*	32	31	32	33
Upper-limb Coordination	*39*	36	37	37	39

Figure 14 is an illustration of early learning during participation in a training programme. After initially struggling with the rhythmic clapping, and understanding the guide sounds, by session three Tom had improved tremendously. His performance earned him a rating in the "exceptional" category.

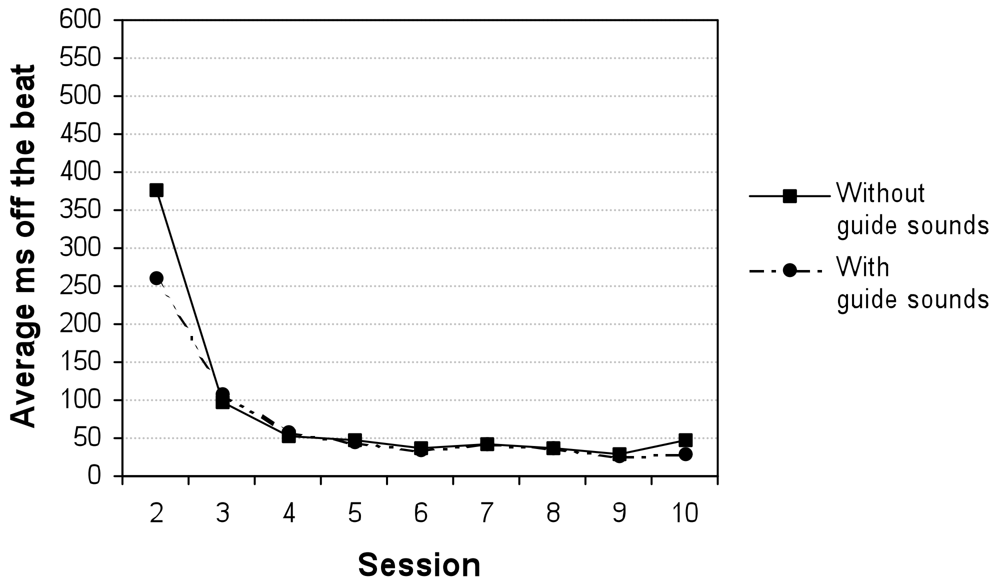


Figure 14. Tom's SFT results over the 10 sessions of the intervention programme.

Tom achieved the largest improvement among all the participants in his performance on the rhythmic tasks, although he was not the highest scorer on the rhythmic tasks. Figure 15 illustrates that participation in the metronome-based training programme led Tom to a consistently successful performance of all the tasks of the LFA. He had particularly weak pre-LFA scores on nine of the 14 tasks. This pattern of improvement is congruent with the SFT results that show how much he improved after the first three intervention sessions.

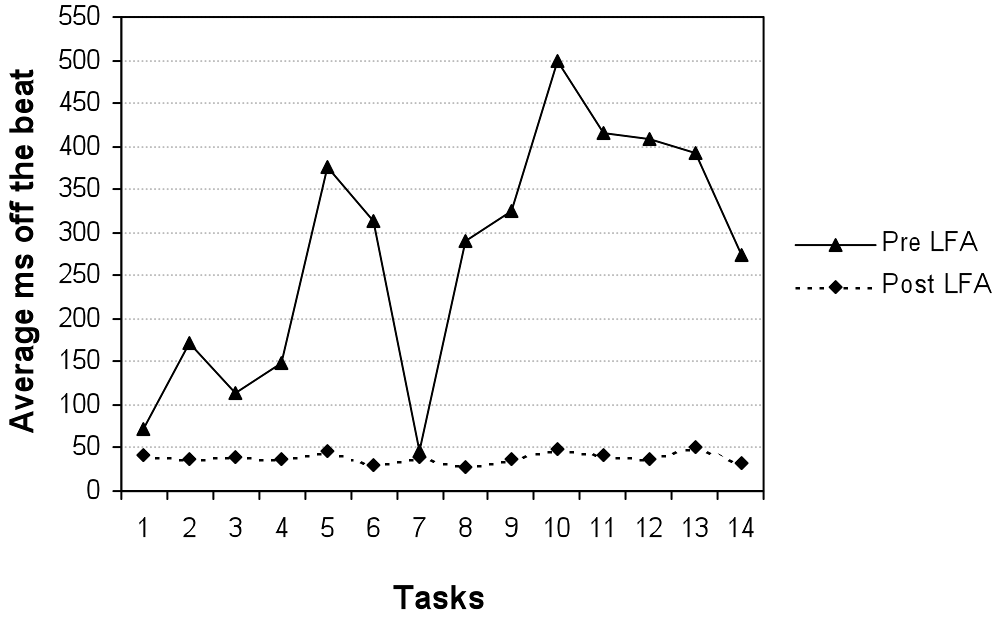


Figure 15. Tom’s pre- and post-test performance on each task of the LFA.

The effects on Tom can be summarised as:

- Small improvement in BOT-2 subtests, but initial scores were relatively high.
- Improvement in bilateral coordination not fully maintained after retention period.
- Very good progress in terms of rhythmic entrainment throughout the intervention programme.
- Consistency in all rhythmic tasks post intervention.

Summary

The answer to the question, “Is a rhythmic entrainment programme helpful for children who display motor development delays?” is not simple. When considering the group data from this study, the results suggest that it may be more helpful for some motor variables than for others. The significant improvement in bilateral coordination after the intervention suggests that the metronome-based training programme did indeed have a positive effect on the children’s bilateral coordination (as measured by the BOT-2). The balance and upper-limb coordination subtests results are not as straightforward. The metronome-based training programme’s effect on balance does not appear to affect the balance scores much as these scores remain relatively consistent over time. The upper-limb coordination group data demonstrates a learning curve, which suggests that familiarisation and/or learning took place over the testing sessions. However, a test that is more discriminatory may have indicated different results. The BOT-2 may have limited the outcome of the study because of the ceiling placed on the number of trials the children were allowed to do, therefore further progress cannot be accounted for.

With regard to the individual results, it is clear that the children all reacted differently to the intervention. Firstly the children scored differently on the three subtests, and their progress throughout the study was also individual. Some of the children showed great improvements in the BOT-2 subtests, while others showed relatively small changes. The different responses to the intervention were evident in the individual SFT and LFA graphs. These graphs highlighted the uniqueness of children and the well-accepted notion that one intervention may be more effective for some children than for others. Most of the improvements that were registered following participation in the intervention programme were maintained during the retention period, which suggests that the entrainment process had a relatively lasting effect. However, there were some children who scored lower on the retention test in comparison to the post-test, which suggested that these children could have benefited from a longer intervention period for the metronome-based training programme or a different approach to improving their bilateral coordination, balance and/or upper-limb coordination.

Chapter Five

Conclusions

The findings in this study are mixed. Bilateral coordination was shown to improve significantly after the rhythmic entrainment intervention, and this was retained after a retention period. However, the other two variables did not show the same pattern. The balance of the children was not shown to improve significantly. Changes in upper-limb coordination seemed to follow a learning or familiarisation curve, leaving the effect of the rhythmic entrainment on this variable inconclusive. Some of the individual children showed substantial improvements after the rhythmic entrainment programme, which makes this intervention a promising addition to the collection of training programme options available to help children who have developmental delays or coordination problems.

Thoughts on Training Programmes

With regard to rhythmic entrainment studies (Bartscherer & Dole, 2005; Jacokes, 2004; Libkuman *et al.,* 2002; Shaffer *et al.*, 2001; Zachopoulou & Mantis, 2001) the literature is also very promising, as the studies that have been conducted have demonstrated that most of the motor skills that have been assessed have shown improvement. Other programmes involving rhythmic accompaniment have found this to be a valuable method of instruction. The study by Beisman (1967) found that teaching fundamental movement skills with rhythmic accompaniment led to improvements in quantity and quality of the selected fundamental motor skills. Studies by Derri *et al*. (2001a) and Zachopoulou *et al.* (2004) which also integrated music and movement also found significant improvements in the fundamental motor skills of concern.

There is a limited amount of literature about the effects of rhythmic training on motor control and motor learning. Previous research focused on the various uses of rhythmic accompaniment, have found that the addition of rhythm to a movement programme appears to facilitate the improvement of some motor skills. Auditory rhythmic stimulation has been shown to improve the learning of movement skills (Zachopoulou *et al*., 2004; Derri *et al*., 2001a; Prassas *et al*., 1997; Brown *et al.*, 1981; Beisman, 1967). While it is acknowledged that each individual's reaction to a specific programme is unique, there is general consensus that rhythm-based training may be beneficial for many children with or without movement problems (Bartscherer & Dole, 2005; Derri *et al*., 2001a; Thomas & Moon, 1976). This conclusion makes the study of rhythm-based training and rhythmic entrainment a very exciting field that has a huge potential for further exploration.

In terms of Burton's (1990) description of a strategy for improving coordination difficulties it would seem that the intervention programme implemented in this study was a neuromotor approach, addressing the development and entrainment of coordinative structures. The simple movement tasks in the programme were designed to guide the individuals toward establishing a more coordinated attractor state. Although the results were reported in terms of group findings, examples of individual results were also provided. These two different ways of looking at the results reinforces Parker and Larkin's (2003) position that programmes must be examined both in terms of group and individual effects, because each individual bring his/her own neuromotor constraints to movement performance.

Thoughts on Timing and Coordination

The results of this study are compatible with both traditional Schema Theory and contemporary Dynamic Systems Theory. From a traditional approach, Thaut *et al.* (1999) found that external auditory stimuli interact with the motor systems, which results in the increased symmetry of muscle activation patterns. The rhythmic accompaniment is thought to act as an external timekeeper, which through the interactions with the motor control systems, leads to stability and accuracy of movement performance (Thaut *et al*., 1999; Prassas *et al*., 1997).

From a Schema Theory perspective, the internal timekeeper is thought to impact on the timing (which would include the relative timing of the GMP) of movement sequences by influencing on the consistency of the movements. Williams *et al*. (1992) believed that the timing deficits of children who were clumsy were due to a central mechanism, which they postulated to be the internal timekeeper. Ivry and Hazeltine (1995) demonstrated that a stable internal representation of time could be entrained through a rhythmic activities programme, which they suggested led to improved movement performance. The improved representation of time would translate to improvements in the relative timing of the GMP, as well as the overall timing of the schema. The conclusion could be made that the effectiveness of a stable internal timekeeper is entrainable.

The Dynamic Systems Theory does not subscribe to the existence of an internal timekeeper, but rather is based on the premise that timing control emerges from the intrinsic dynamics of the system. These intrinsic dynamics provide the foundation of the perceptual-motor landscape. Therefore in the case of children who are clumsy who have been shown to have timing problems in their movement control, intrinsic dynamics are constrained by their poor timing control which leads to the emergence of less stable coordination patterns as well as motor patterns that are referred to as having a clumsy appearance (Volman & Geuze, 1998; Geuze & Klaverboer, 1994; Williams *et al.*, 1992; Liemohn, 1983).

Although genetic and developmental processes influence the intrinsic dynamics, movement experiences will also have a profound effect (Davids *et al.,* 2008). Davids *et al.* (2008) noted that movement experiences contribute to the establishment of attractor states (at the least traces of attractor states) within the individual's perceptual-motor landscape. When more complex movements are attempted these early attractors, *e.g*. grasping, stepping, balance and locomotion, are organised into more complex actions. Early attractors can be adapted to reorganise the perceptual-motor landscape in new movement situations. For example, if an individual's rhythm and timing control (both functional constraints) act as rate limiters in a movement situation, a stable pattern of interaction among coordinative structures will not emerge. In other words, the intrinsic dynamics are not stable and the resultant perceptual-motor landscape is in a sense rhythmically disordered.

Bilateral Coordination

Volman and Geuze (1998) found that children who were clumsy had poor bilateral coordination stability. It was not surprising, then, when the children in this study also displayed low scores on the bilateral coordination subtest prior to the intervention. Of interest in this study was whether the attractor of bilateral coordination of the children that was found to be poor could be improved through an intervention programme of rhythmic entrainment of very simple movements. The significant improvement achieved at the end of this study suggests that the coupling of coordinative structures had been strengthened, thereby improving the stability of the system.

This improvement in bilateral coordination achieved by the children in this study could be due to their repetitive practising simple movements (the movements set out in the intervention programmes) in time with a simple isochronous rhythm. A strong attractor effect may have been provided by the rhythmic entrainment. The rhythmic entrainment tasks may have acted as a perturbation, capable of causing a phase transition to a more stable attractor state. If this was the case, then there would be a deepening of the well of the attractor which would lead to improved stability. It could be concluded that the attractor states of the intrinsic dynamics of the basic movement patterns of the limbs were enhanced through the rhythmic entrainment process. With the emergence of improved stability of the timing control of the synergies and coordinative structures in movement, the organisation of the body parts in relation to each other could also have improved. The improvement in the bilateral coordination scores of the children suggest that the children had gained more control over their bilateral movements, that their coordinative structures were more tightly coupled, and that they were better able to recruit the correct muscle groups at the right time.

Balance and Upper-limb Coordination

Balance and upper-limb coordination were less affected by the rhythmic entrainment programme. The perceptual-motor abilities involved in the performance of balance and upper-limb coordination tasks are numerous and each one can operate as a constraint. Improving the timing and rhythm aspects of coordination may not be sufficient to affect performance, at least not on the BOT-2 subtest items used for assessment in this study.

Balance is a variable that can be influenced by many individual, task and environmental consideration. Although balance control is regulated by neural messages travelling to the muscles involved in motor performance, the vestibular and visual senses play a critical role in both dynamic and static balance control. If a child has a problem with processing sensory information, balance control may be compromised. These kinds of sensory constraints could serve as rate limiters. When considering the impact of the rhythmic entrainment programme implemented in this study, auditory processing ability would also have to be considered a potential rate limiter. Sensory constraints were not assessed so it is not known whether or not any of the children participating in this study had any sensory problems. It must also be noted that while the training programme did challenge balance control in some the tasks performed *e.g.* performing a task on one foot, the programme did not focus specifically on the development of balance. Despite this lack of specific attention, some individuals did show improvement in their balance scores following the intervention programme.

Researchers (Bartscherer & Dole, 2005; Jacokes, 2004) have reported improvements in balance of children, who had movement problems, but these rhythmic entrainment intervention programmes (similar to the present study) were longer in duration, and therefore the children spent much more time on balance tasks within the intervention programme. Dynamic balance of preschool children was also shown to improve after participation in a relatively long integrated music and movement intervention programme (Zachopoulou *et al.,* 2004). This would suggest that the balance attractor requires more practice to improve the stability of the system. It must be concluded that the intervention programme in the present study was not sufficient to create stability in balance control.

The upper-limb coordination results are more difficult to interpret. As has been noted, the method of scoring on the BOT-2 puts a cap on the number or trials which limits the extent to which the improvement of the upper-limb coordination can be measured. It might be anticipated that the improved stability of the bilateral coordination attractor would translate to improved performance of the upper-limb coordination subtest items. However, it does not appear that the improved coupling of the coordinative structures for the bilateral coordination items had an impact on the upper-limb coordination items.

It must be acknowledged that the nature of the tasks involved in the upper-limb coordination evaluation (catching and throwing) are very complex, relative to the complexity of the bilateral coordination tasks, and therefore there are a myriad of constraints which can act as rate limiters. Increased complexity means that the children are faced with more degrees of freedom, as well as more constraints and rate limiters that will influence the establishment of coordinative structures. A study with 8 to 10 year old tennis players (Zachopoulou & Mantis, 2001) found that performance stability (measured by the number of correct attempts) was shown to improve after participation in a rhythmic entrainment intervention programme. These results suggest that entrainment experiences have the potential to improve the stability of an attractor state. However, it must be noted that the children in this study were tennis players and their results may not be applicable to the children in this study who had been identified as having coordination difficulties:

- The tennis players would probably have had a more stable attractor state prior to the programme.
- Children with coordination difficulties may take a longer period to establish stability in the coordination tasks which involve a number of constraints.
- Perhaps a different assessment instrument would have yielded different results. The BOT-2 upper-limb coordination subtest comprised of seven items, where the research with the tennis players only required that they perform one tasks.

Concluding Thoughts about the Programme

With regard to the present study, the metronome-based programme was an attempt to stabilise the attractors for bilateral coordination, balance and upper-limb coordination. The participants in the present study were children who had been identified by their teachers as displaying motor skill development delays. The premise of the intervention programme was that timing deficit contributed to the movement coordination difficulties that are taken as signs of these delays. By providing tasks using an isochronous beat as a cue for movement performance, the intention of the programme was to develop stability in the control of movement by reducing the inconsistency of movement patterns (Thaut *et al.*, 1999).

The repetitive nature of the metronome-based intervention called for the participant to focus on precise control in movement task performance (tapping on the beat) which is thought to improve the neural capacity for controlling movement (Diamond, 2003). The repetitive practice aspect of the programme is also proposed to improve the motor planning and sequencing of motor skills, therefore the motor actions become more organised, effective and efficient which translates to improved performance of motor skills (Diamond, 2003).

It cannot be concluded with certainty that the significant improvement in bilateral coordination was a result of an improvement either in some kind of internal timekeeper (Bartscherer & Dole, 2005) or in the stability of the attractor for timing control. It must be remembered that the tasks in the training programme that required bilateral coordination may have strengthened neuromuscular pathways that supported the performance of the bilateral coordination tasks on the BOT-2. The metronome beat in this case, may not only have acted as an attractor to improve symmetry and organisation of the neural firing, but also provided a cue for practising specific movement patterns.

Recommendations for Future Programmes

In reflecting on the outcome as well and the experience of presenting the intervention programme, the researcher proposes the following:

- Each child represents a unique system, and brings different dynamics to the situation. Therefore, for future programmes it would be more beneficial to each child to have a programme tailored to his/her specific strengths and weaknesses.

- In order to tailor programmes specifically to each child, an individualised assessment strategy also must be designed.

- Some children could have benefited from a longer intervention period, therefore each child should be continually evaluated to determine when they have received maximum benefit.

- Although this study was bound by the implementation of only a rhythmic entrainment programme, intervention programmes that include strategies to address other constraints/rate limiters of children's motor performance may be a more effective way to address the development of coordination.

Future Research

The results of this study certainly raise intriguing questions for the researcher in terms of future investigations.

- The BOT-2 is an assessment instrument with limitations in the research environment (Burton & Miller, 1998). In terms of studying coordination, the fact that the kinematics of task performance is not evaluated is one such limitation. This means that a child may have improved the quality of their coordination, but not their score on the subtests. Future research could include biomechanical or visual observation performance analysis to detect the improvement in flow, smoothness and control of movements. The researcher had the perception that the children participating in this study all improved the quality of their movement performance after participation in the intervention programme, but there was no data to support this.

- It is usually desirable to have a larger sample size in order to gain insight into the effects of any intervention programme. It is also desirable to have a control group. However, a control group should be chosen with caution due to the heterogeneity of children. It would be interesting to determine how much of a factor the rhythmic movements and auditory feedback were in the effect on the results. For that reason, it would have been helpful to have a group who performed the intervention tasks without the benefit of rhythmic entrainment in order to make a comparison.

- Timing and rhythm are recognised as critical dimensions of coordination and are underlying factors of skilled performance. Because there is evidence that indicates positive effects for rhythmic entrainment on golfing accuracy (Libkuman *et al*., 2002), research to study the effects of rhythmic entrainment programmes for elite level performers would be interesting.

Conclusion

In conclusion, it appears that a rhythmic entrainment intervention programme is a promising approach to addressing some of what Burton (1990) described as the neuromotor limitations of individuals who have coordination difficulties. The relationship between intervention programmes that address timing of movement and improvements in coordination can be explained through either the Schema Theory or the Dynamic Systems Theory. Although both theoretical approaches offer alternate explanations, it would seem that both approaches are compatible with the future construction of a rationale to validate rhythmic intervention strategies.

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Appendix A

Descriptions of Tasks and Score Indicator Table

The following Appendix includes descriptions of the tasks (Figure 16) as well as the description of the scores (Figure 17) as provided by the manufacturer which were used as indicators to interpret the scores achieved on the LFA and SFT.

Number	Task	Limbs and Type of Movement Involved	Description
1	Both Hands	Upper limb Bilateral	Both hands are moved in a rhythmic outward circular motion, and the trigger is hit when the hands meet at the midline.
2	Right Hand	Upper limb Unilateral	The right hand hits the upper right thigh as it makes a rhythmic outward horizontal circular motion.
3	Left Hand	Upper Limb Unilateral	The left hand hits the upper left thigh as it makes a rhythmic outward horizontal circular motion.
4	Both Toes	Lower limb Bilateral	From a standing position where weight evenly distributed, one foot moves forward and with the toes taps the foot trigger pad, before returning to the start position. Feet are alternated.
5	Right Toe	Lower limb Unilateral	The left foot supports the individual's weight, while the toes of the right foot are tapped on the foot trigger pad. The heel of the right foot remains on the floor.

Number	Task	Limbs and Type of Movement Involved	Description
6	Left Toe	Lower limb Unilateral	The right foot supports the individual's weight, while the toes of the left foot are tapped on the foot trigger pad. The heel of the left foot remains on the floor.
7	Both Heels	Lower limb Bilateral	The individual stands with their back to the foot trigger pad. One foot moves backward and with the heel taps the foot trigger pad, before returning to the start position. Feet are alternated.
8	Right Heel	Lower limb Unilateral	The left foot supports the individual's weight, while the heel of the right foot is tapped on the foot trigger pad. The toes of the right foot remains on the floor.
9	Left Heel	Lower limb Unilateral	The right foot supports the individual's weight, while the heel of the left foot is tapped on the foot trigger pad. The toes of the left foot remains on the floor.
10	Right Hand – Left Toe	Upper and lower limbs Bilateral	A combination between task 2 and 6. The individual alternates between tapping the right hand on the right thigh and tapping the left toes on the foot trigger pad.
11	Left Hand – Right Toe	Upper and lower limbs Bilateral	A combination between task 3 and 5. The individual alternates between tapping the left hand on the left thigh and tapping the right toes on the foot trigger pad.

Number	Task	Limbs and Type of Movement Involved	Description
12	Balance Right Foot – Tap Left Foot	Lower limb Balance Bilateral	The individual balances on the right leg, while the left foot is lifted into the air. The left toes then tap on the foot trigger pad by extending and flexing the knee.
13	Balance Left Foot – Tap Right Foot	Lower limb Balance Bilateral	The individual balances on the left leg, while the right foot is lifted into the air. The right toes then tap on the foot trigger pad by extending and flexing the knee.
14	Both Hands	Upper limb Bilateral	As for task 1, but with guide sounds.

Figure 16. A description of the tasks performed in the LFA, SFT and intervention.

Age	9 – 10	11 – 12
Extreme Deficiency	260+	240+
Severe Deficiency	160 – 259	155 – 239
Below Average	80 – 159	75 – 154
Average	55 – 79	45 – 74
Above Average	38 – 54	36 – 44
Exceptional	28 – 37	26 – 35
Superior	Below 28	Below 26

Figure 17. The relevant scores of the indicator table as provided by the manufacturer (Interactive Metronome, 2007) to assist in interpretation of scores. Scores are given in milliseconds.

Appendix B

Information sheet

Title of study: *The effect of coordination training programme on the fundamental gross motor skills of children.*

The aim of the project is to determine whether eleven 30-minute sessions of metronome-based coordination training will lead to improvements of gross motor skills which will be assessed using subtests of the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition.

Childhood is a critical time for the development of fundamental gross motor skills. The fundamental skills serve as a base for learning more complex motor skills. Gross motor skills require the coordination of all the body parts to move as a cooperative whole in order for the movement to be performed successfully.

Coordination abilities, which have been sighted as major determinants of motor ability and motor achievement, must be developed during childhood to enable children to perform coordinated actions. Good rhythmicity and timing are underlying features of good coordination and are seen as important factors in the development, learning and performance of motor skills. Development of fundamental motor skills is associated with the development of rhythmic ability. The development of a timing control mechanism is essential for learning rhythmic coordinated movements, as a lack of timing control may result in poor rhythmic movement skills as has been found in clumsy children. Skilled movements require precise timing in the activation of the various muscles involved in the movements.

The training programme is based on the theory that rhythm and timing are essential components of coordination. This training enables individuals to practise and improve their timing and rhythm and through improving these vital abilities potentially lead to improvements in the performance of a range of motor skills. The training will require your child to perform movements in time to a beat. The goal of the training is to make the movement as close to the beat as possible.

During training your child will wear a set of headphones through which he/she will hear metronomic beats, and gloves with sensors on his/her hands. There will also be a footpad with sensors in that will be placed on the floor. The sensor on the glove and the footpad are activated when the child taps his/her hand or foot against it. A computer programme detects the activation of the sensor and stores the response times on the computer. The participant will receive audio feedback to indicate how accurate the movement is. This feedback allows the participant to become progressively more accurate in the exercises. The equipment is safe to use with children.

Testing will follow the protocol as set out by the Bruininks-Oseretsky Test of Motor Proficiency and will involve throwing, catching, running, jumping and balancing. The researcher and assistants are trained to administer the test items.

The testing and training sessions will be conducted during break periods at school. The schedule will be worked out with the principal and the teachers. The children will complete 11 training sessions over a period of three weeks. There will only be one training session per day. The training sessions will be approximately 30 minutes long.

There will be no dangerous or invasive procedures. There are no risks involved with the testing and training procedures. The equipment used is safe to use with children. If the participant experiences any discomfort at any time during the testing or training programme he/she may stop with no penalty. The testing and training procedures constitute no more risk than those normally experienced by children during regular physical education classes.

The researcher is a certified provider of the training programme. This programme will be given free of charge, and your child will not receive payment for his/her participation. In the past 2 years the researcher has regularly worked at the school assisting children from all the different grades with the development and movement skills. The children are used to the researcher working with groups or individuals so the sessions will not be seen as unusual. The specific intervention will be presented to the children as part of a project to help the researcher understand how specific equipment can be used. During the participation in the sessions themselves, the children will be encouraged to share their feelings about participating in the sessions. If a child shares any negative feelings or reports feeling labelled in any way, the investigator will immediately discuss the situation with his/her teacher in order to address the situation. Therefore utmost care will be taken to ensure minimise the risk of negative labelling occurring.

The information and results from the tests will be kept confidential and only be shared with my supervisor. The results will be used in a research report to be published in a Masters thesis and a research journal, but for these purposes each child will be assigned a code number and therefore will remain anonymous. The results of the project can also have possible implications for future training programmes and will be used for this purpose.

Your child's participation in this study is purely voluntary, and you and your child may decide to participate or not. Your child is free to withdraw from the study at any time with no penalty. If circumstances arise, the researcher may also choose to withdraw your child from the study.

For any questions or queries contact:

Jessie Scott: 072 2360963
Prof. E.S. Bressan: 021 8084722

Appendix C

Informed Consent

The effect of a coordination training programme on the fundamental gross motor skills of children.

Reference number:____

Consent from participant's parent/guardian:

I, ____

(mother/father/guardian) of ____

From (address)____

____

____

Confirm that:

1. My child was invited to participate in the above-mentioned project conducted by Jessie Scott (BSc Hons. Sport Science) from the Department of Sport Science at Stellenbosch University. The results of the study will form part of a Masters thesis, which may be published. My child may be selected as a possible participant because he/she is between 9 and 12 years old.

2. It was explained to me that:

2.1. The aim of the project is determine whether a metronome-based coordination training programme has an effect on fundamental gross motor skills of children.

3. Procedures

3.1. My child will complete the subtests of Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) which will take approximately one hour. This test consists of skills such as throwing, catching, running, jumping and balancing.

3.2. The BOT-2 is the property of the motor learning laboratory at the Sport Science Department.

3.3. Once the results of the test are assessed and if my child scores below the average scores of his/her peers he/she may be invited to participate in the training programme.

3.4. The training programme will be conducted by the researcher who is a certified trainer in this field of work and has experience of working with children.

3.5. The training will involve 11 sessions that will take place over a period of three weeks. There will only be one session a day of approximately 30 minutes.

3.6. The coordination training will involve activities such as clapping hands together, tapping hand on the thigh, tapping toe or heel on the floor, alternating foot taps, alternative hand and heel taps in time to a beat.

3.7. The BOT-2 will be re-administered after my child has completed the week of training. The test will also be re-administered 4 weeks after that.

3.8. The project will last for a total period of 11 weeks, however active daily participation will only be over a period of three weeks.

3.9. The testing and training will take place at school. The training sessions will be run during break periods during school hours. A schedule will be worked out with the principal and the teachers.

4. Potential risks and discomforts

4.1. No dangerous or invasive procedures or administration of any substances form part of this project.

4.2. Utmost care will be taken by the researcher to ensure that my child will not experience negative labelling when taking part in the testing and training sessions.

4.3. There are no risks involved with this study. The BOT-2 is specifically designed for children (4.5 to 14.5 years) and the intervention consists of playful activities of low intensity. The activities will not be unlike those experienced during physical education classes.

4.4. During training my child may wear a glove that has a sensor attached to it. The sensor will be triggered every time it is tapped. There will be no discomfort experienced from wearing the glove or tapping the sensor. My child will also wear headphones through which he/she will hear the metronomic beats. A computer programme detects the activation of the sensor and stores the response times on the computer. My child will receive audio feedback to indicate how accurate the movement is. This feedback will allow my child to become progressively more accurate in the exercises. The equipment that will be used is safe to use with children.

4.5. I understand that if my child experiences any discomfort at any time during the testing or training programme he/she may stop.

5. Potential benefits

5.1. The coordination training can potentially improve my child's gross motor skills.

5.2. The results will assist in designing physical education and sport training programmes for other children.

6. Payment for participation

6.1. My child will not be paid for his/her participation in this study.

7. Confidentiality

7.1. Any information that is obtained in connection with this study and that can be identified with my child will remain confidential and will be disclosed only with my permission or as required by law. Confidentiality will be maintained by means of my child receiving a code and from then on being identified by this code. The data will be stored on the researcher's password controlled computer and printed material will be stored in a locked cabinet, which only the researcher and her supervisor have access to.

7.2. The results will also be shared with the researcher's supervisor, Prof. Elizabeth Bressan.

7.3. The results from the study will be published in a master's thesis and a research journal, but my child will be identified by the code that he/she has been assigned and therefore remain anonymous.

8. Participation and withdrawal

8.1. I can choose whether I want my child to be part of this study or not. If my child does volunteer to be in this study, he/she may withdraw at any time without consequence of any kind. My child and I may refuse to answer any questions we don't want to answer and he/she will still remain in the study. The researcher may withdraw my child from this research if circumstances arise which warrant doing so.

9. Identification of investigators

9.1. If I have any questions or concerns about the research, I may contact:
Jessie Scott: cell: 0722360963
Prof. Elizabeth Bressan: work: 021 8084722

10. Rights of research subjects

10.1. I may withdraw my consent at any time and have my child discontinue participation without penalty. I am not waiving any legal claims, rights or remedies because of my child's participation in this research study. If I have any questions regarding my child's rights as a research participant I can contact Maryke Hunter-Hüsselmann (mh3@sun.ac.za; 0218084623) at the Unit for Research Development of Stellenbosch University.

11. I was provided with information about this project. I was also given an opportunity to ask questions and all my questions were answered satisfactorily.

I hereby consent voluntarily to allow my child to participate in this study. I have been given a copy of this form.

Signed at ________________________ on _____________ 2008

_________________________ _____________________________
Mother/Father/Guardian's name Signature

<u>STATEMENT OF THE RESEARCHER</u>

I, *Jessie Scott* declare that I:

1. Explained the information contained in this document to ______________
2. Requested the parent/guardian to ask questions if anything was unclear.
3. Performed this conversation in English after determining that the participant was in command of this language.

Signed at ________________________ on _________________ 2008

_________________________ _____________________________
Researcher's name Signature

Appendix D

Shortened Informed Consent

English version

Dear Parent/Guardian

Your child, ... , has been chosen to take part in a movement programme that will be presented by Jessie Scott who is a masters student. The programme forms part of her thesis. The programme involves rhythmic movement. The programme will be run during normal school hours.

All results will be kept confidential. There is no injury risk to your child. There is no cost involved with this programme.

For any queries please contact:
Jessie Scott: 0722360963
Prof. Bressan: 021 8084722

Kind Regards,

Jessie Scott

✂ --

.... (Child's name)

☐ Yes, my child may participate.
☐ No, my child may not participate.

....
Signature (Parent/Guardian) Date

Stellenbosch University
Department of Sport Science

Jessie Scott: 0722360963
Prof. Bressan: 0218084722

Afrikaans version

Beste Ouer/Voog,

Jou kind,…………………….., is gekies om in 'n bewegings program deel te neem wat deur 'n meesters student, Jessie Scott aangebied gaan word. Die program vorm deel van haar tesis en behels die aanleer van ritmiese bewegings. Hierdie program sal gedurende gewone skool tyd aangebied word.

Alle resultate van hierdie program sal konfidensieel opgeneem word. Daar is geen beseringsrisiko en finansiele kostes verbonde aan hierdie program nie.

Vir enige navrae skakel asseblief:
Jessie Scott: 0722360963
Prof. Bressan: 021 8084722

Met danke,

Jessie Scott

✂ --

.... (kind se naam)

☐Ja, my kind mag deelneem.
☐ Nee, my kind mag nie deelneem nie.

....
Handtekening (Ouer/Voog)   Datum

Stellenbosch University
Department of Sport Science

Jessie Scott: 0722360963
Prof. Bressan: 0218084722

Appendix E

Score Sheet

The following Appendix includes the BOT-2 (Bruininks & Bruininks, 2005) subtest score sheets used for the assessment procedure in the study.

Name:__________________________________ **Date:** ___________

Gender: M/F **Dominant hand: R/L** **Dominant foot: R/L**

Subtest 4: **Bilateral Coordination**

Conduct the second trial only if the examinee does not earn the maximum score on the first trial.

	Raw Score Trial 1	Raw Score Trial 2								Point Score
1 Touching Nose with Index Fingers—Eyes Closed	touches	touches	Raw	0	1	2	3	4		
			Point	**0**	**1**	**2**	**3**	**4**		
2 Jumping Jacks	jumping jacks	jumping jacks	Raw	0	1	2–4	5			
			Point	**0**	**1**	**2**	**3**			
3 Jumping in Place—Same Sides Synchronized	jumps	jumps	Raw	0	1	2–4	5			
			Point	**0**	**1**	**2**	**3**			
4 Jumping in Place—Opposite Sides Synchronized	jumps	jumps	Raw	0	1	2–4	5			
			Point	**0**	**1**	**2**	**3**			
5 Pivoting Thumbs and Index Fingers	pivots	pivots	Raw	0	1	2–4	5			
			Point	**0**	**1**	**2**	**3**			
6 Tapping Feet and Fingers—Same Sides Synchronized	taps	taps	Raw	0	1	2–4	5–9	10		
			Point	**0**	**1**	**2**	**3**	**4**		
7 Tapping Feet and Fingers—Opposite Sides Synchronized	taps	taps	Raw	0	1	2–4	5–9	10		
			Point	**0**	**1**	**2**	**3**	**4**		

Notes & Observations

Total Point Score Subtest 4 (max = 24)

Subtest 5: **Balance**

Conduct the second trial only if the examinee does not earn the maximum score on the first trial.

	Raw Score Trial 1	Raw Score Trial 2								Point Score
1 Standing with Feet Apart on a Line—Eyes Open (10 sec)	seconds	seconds	Raw	0.0–0.9	1.0–2.9	3.0–5.9	6.0–9.9	10		
			Point	**0**	**1**	**2**	**3**	**4**		
2 Walking Forward on a Line	steps	steps	Raw	0	1–2	3–4	5	6		
			Point	**0**	**1**	**2**	**3**	**4**		
3 Standing on One Leg on a Line—Eyes Open (10 sec)	seconds	seconds	Raw	0.0–0.9	1.0–2.9	3.0–5.9	6.0–9.9	10		
			Point	**0**	**1**	**2**	**3**	**4**		
4 Standing with Feet Apart on a Line—Eyes Closed (10 sec)	seconds	seconds	Raw	0.0–0.9	1.0–2.9	3.0–5.9	6.0–9.9	10		
			Point	**0**	**1**	**2**	**3**	**4**		
5 Walking Forward Heel-to-Toe on a Line	steps	steps	Raw	0	1–2	3–4	5	6		
			Point	**0**	**1**	**2**	**3**	**4**		
6 Standing on One Leg on a Line—Eyes Closed (10 sec)	seconds	seconds	Raw	0.0–0.9	1.0–2.9	3.0–5.9	6.0–9.9	10		
			Point	**0**	**1**	**2**	**3**	**4**		
7 Standing on One Leg on a Balance Beam—Eyes Open (10 sec)	seconds	seconds	Raw	0.0–0.9	1.0–2.9	3.0–5.9	6.0–9.9	10		
			Point	**0**	**1**	**2**	**3**	**4**		
8 Standing Heel-to-Toe on a Balance Beam (10 sec)	seconds	seconds	Raw	0.0–0.9	1.0–2.9	3.0–5.9	6.0–9.9	10		
			Point	**0**	**1**	**2**	**3**	**4**		
9 Standing on One Leg on a Balance Beam—Eyes Closed (10 sec)	seconds	seconds	Raw	0.0–0.9	1.0–2.9	3.0–4.9	5.0–7.9	8.0–9.9	10	
			Point	**0**	**1**	**2**	**3**	**4**	**5**	

Notes & Observations

Total Point Score Subtest 5 (max = 37)

Subtest 7: **Upper-Limb Coordination**

For Items 5 and 6, conduct the second trial only if the examinee does not earn the maximum score on the first trial.	Raw Score: Trial 1	Raw Score: Trial 2										Point Score
1 Dropping and Catching a Ball—Both Hands	catches		Raw	0	1	2	3	4	5			
			Point	**0**	**1**	**2**	**3**	**4**	**5**			
2 Catching a Tossed Ball—Both Hands	catches		Raw	0	1	2	3	4	5			
			Point	**0**	**1**	**2**	**3**	**4**	**5**			
3 Dropping and Catching a Ball—One Hand	catches		Raw	0	1	2	3	4	5			
			Point	**0**	**1**	**2**	**3**	**4**	**5**			
4 Catching a Tossed Ball—One Hand	catches		Raw	0	1	2	3	4	5			
			Point	**0**	**1**	**2**	**3**	**4**	**5**			
5 Dribbling a Ball—One Hand	dribbles	dribbles	Raw	0	1	2	3	4–5	6–7	8–9	10	
			Point	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
6 Dribbling a Ball—Alternating Hands	dribbles	dribbles	Raw	0	1	2	3	4–5	6–7	8–9	10	
			Point	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
7 Throwing a Ball at a Target	throws		Raw	0	1	2	3	4	5			
			Point	**0**	**1**	**2**	**3**	**4**	**5**			

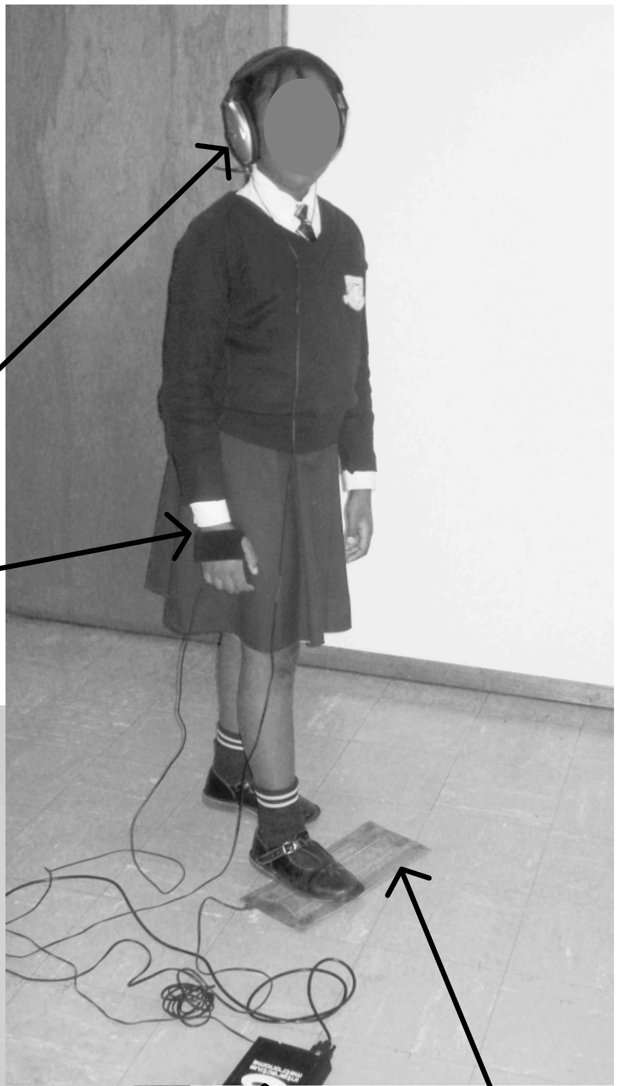
Notes & Observations

Total Point Score Subtest 7 (max = 39)

Appendix F

Pictures to Illustrate IM Set-up

The pictures below illustrate the set-up involved for the training programme which was used as the intervention in this study. One can see the headphones through which the individual hears the reference tone as well as the guide sounds. The hand glove, with the sensor attached and the footpad are the sensors which the individual is required to tap to illicit a response. These are attached to the control box, which in turn is attached to the computer which runs the software.




Appendix G

Intervention Sessions

The following Appendix includes all the intervention’s session plans.

Abbreviations:

- LFA: Long Form Assessment
- SFT: Short Form Test
- RT: Regular Training
- RO: Right-on (Rubber tang sound)
- G: Guide (Buzzer sound)

<table>
<tr><th colspan="7">Session 1</th></tr>
<tr><th>Setting</th><th>Task</th><th>Repetitions</th><th>Difficulty</th><th>Guide Sound</th><th>Position</th><th>Additional</th></tr>
<tr><td>RT</td><td>1</td><td>10</td><td>100</td><td>Off</td><td>Seated</td><td></td></tr>
<tr><td rowspan="14">Pre-LFA</td><td>1</td><td>54</td><td rowspan="14">100</td><td rowspan="13">Off</td><td>Seated</td><td></td></tr>
<tr><td>2</td><td rowspan="12">30</td><td rowspan="12">Standing</td><td rowspan="12">For the children that battled with balance a chair was put in place to hold on to.</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td></tr>
<tr><td>6</td></tr>
<tr><td>7</td></tr>
<tr><td>8</td></tr>
<tr><td>9</td></tr>
<tr><td>10</td></tr>
<tr><td>11</td></tr>
<tr><td>12</td></tr>
<tr><td>13</td></tr>
<tr><td>14</td><td>54</td><td>On</td><td>Seated</td><td></td></tr>
<tr><td></td><td>Total:</td><td>468</td><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><th colspan="7">Session 2</th></tr>
<tr><th>Setting</th><th>Task</th><th>Repetitions</th><th>Difficulty</th><th>Guide Sound</th><th>Position</th><th>Additional</th></tr>
<tr><td>RT</td><td>1</td><td>10</td><td>100</td><td>Off</td><td>Seated</td><td></td></tr>
<tr><td rowspan="2">SFT</td><td>1</td><td rowspan="2">54</td><td rowspan="2">100</td><td>Off</td><td rowspan="2">Seated</td><td rowspan="5"></td></tr>
<tr><td>14</td><td>On</td></tr>
<tr><td rowspan="9">RT</td><td>1</td><td>108</td><td rowspan="3">100</td><td rowspan="3">Off</td><td>Seated</td></tr>
<tr><td>2</td><td rowspan="2">80</td><td rowspan="2">Standing</td></tr>
<tr><td>3</td></tr>
<tr><td>1</td><td rowspan="3">54</td><td rowspan="6">300</td><td rowspan="6">On</td><td rowspan="3">Seated</td><td rowspan="6">Volume Setting: G & RO=10</td></tr>
<tr><td>1</td></tr>
<tr><td>1</td></tr>
<tr><td>2</td><td rowspan="3">108</td><td rowspan="3">Standing</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
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Session 3

Setting	Task	Repetitions	Difficulty	Guide Sound	Position	Additional
RT	1	10	100	Off	Seated	
SFT	1	54	100	Off	Seated	
	14			On		
RT	1	80	300	On	Seated	Volume Setting: G & RO=10
	2	54			Standing	
	3					
	1	108			Seated	
	5	54			Standing	
	6					
	12					
	13					
	Total:	620				

Session 4

Setting	Task	Repetitions	Difficulty	Guide Sound	Position	Additional
RT	1	10	100	Off	Seated	
SFT	1	54	100	Off	Seated	
	14			On		
RT	1	108	300	On	Seated	Volume Setting: G & RO=10
	3	80			Standing	
	2					
	5	54				
	6					
	12					
	13					
	1		200		Seated	
	Total:	672				

Session 5

Setting	Task	Repetitions	Difficulty	Guide Sound	Position	Additional
RT	1	10	100	Off	Seated	
SFT	1	54	100	Off	Seated	
	14			On		
RT	1	108	200	On	Seated	
	1					
	2	54			Standing	
	3					
	4					
	7					
	8	40				
	9					
	Total:	620				

<table>
<tr><th colspan="7">Session 6</th></tr>
<tr><th>Setting</th><th>Task</th><th>Repetitions</th><th>Difficulty</th><th>Guide Sound</th><th>Position</th><th>Additional</th></tr>
<tr><td>RT</td><td>1</td><td>10</td><td>100</td><td>Off</td><td>Seated</td><td></td></tr>
<tr><td rowspan="2">SFT</td><td>1</td><td rowspan="2">54</td><td rowspan="2">100</td><td>Off</td><td rowspan="2">Seated</td><td rowspan="9"></td></tr>
<tr><td>14</td><td>On</td></tr>
<tr><td rowspan="7">RT</td><td>1</td><td>164</td><td rowspan="5">200</td><td rowspan="7">On</td><td>Seated</td></tr>
<tr><td>2</td><td rowspan="2">108</td><td rowspan="6">Standing</td></tr>
<tr><td>3</td></tr>
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<tr><td>9</td></tr>
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<table>
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<tr><td rowspan="2">SFT</td><td>1</td><td rowspan="2">54</td><td rowspan="2">100</td><td>Off</td><td rowspan="2">Seated</td><td rowspan="10"></td></tr>
<tr><td>14</td><td>On</td></tr>
<tr><td rowspan="8">RT</td><td>1</td><td>164</td><td rowspan="8">100</td><td rowspan="8">On</td><td>Seated</td></tr>
<tr><td>10</td><td rowspan="3">54</td><td rowspan="7">Standing</td></tr>
<tr><td>11</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td><td rowspan="2">108</td></tr>
<tr><td>6</td></tr>
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<table>
<tr><th colspan="7">Session 8</th></tr>
<tr><th>Setting</th><th>Task</th><th>Repetitions</th><th>Difficulty</th><th>Guide Sound</th><th>Position</th><th>Additional</th></tr>
<tr><td>RT</td><td>1</td><td>10</td><td>100</td><td>Off</td><td>Seated</td><td></td></tr>
<tr><td rowspan="2">SFT</td><td>1</td><td rowspan="2">54</td><td rowspan="2">100</td><td>Off</td><td rowspan="2">Seated</td><td rowspan="9"></td></tr>
<tr><td>14</td><td>On</td></tr>
<tr><td rowspan="7">RT</td><td>1</td><td>164</td><td rowspan="7">100</td><td rowspan="7">On</td><td>Seated</td></tr>
<tr><td>7</td><td rowspan="4">108</td><td rowspan="6">Standing</td></tr>
<tr><td>4</td></tr>
<tr><td>8</td></tr>
<tr><td>9</td></tr>
<tr><td>12</td><td rowspan="2">54</td></tr>
<tr><td>13</td></tr>
<tr><td></td><td>Total:</td><td>812</td><td colspan="4"></td></tr>
</table>

Session 9						
Setting	Task	Repetitions	Difficulty	Guide Sound	Position	Additional
RT	1	10	100	Off	Seated	
SFT	1	54	100	Off	Seated	
	14			On		
RT	1	162	100	On	Seated	
	10	108			Standing	
	11					
	4					
	5	80				
	6					
	Total:	754				

Session 10						
Setting	Task	Repetitions	Difficulty	Guide Sound	Position	Additional
RT	1	10	100	Off	Seated	
SFT	1	54	100	Off	Seated	
	14			On		
RT	4	180	100	On	Standing	
	10	120				
	11					
	7	140				
	12	40				
	13					
	Total:	748				

Session 11						
Setting	Task	Repetitions	Difficulty	Guide Sound	Position	Additional
RT	1	10	100	Off	Seated	
Post-LFA	1	54	100	Off	Seated	
	2	30			Standing	
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	10					
	11					
	12					
	13					
	14	54		On	Seated	
	Total:	468				

Appendix H

RHYTHMIC ACTIVITY MINI-WORKSHOP

Presented by: Jessie Scott

Introduction

Childhood is a critical time for the development of fundamental gross motor skills. The fundamental skills serve as a base for learning more complex motor skills. Gross motor skills require the coordination of all the body parts to move as a cooperative whole in order for the movement to be performed successfully.

Coordination abilities, which have been sighted as major determinants of motor ability and motor achievement, must be developed during childhood to enable children to perform coordinated actions. Good rhythmicity and timing are underlying features of good coordination and are seen as important factors in the development, learning and performance of motor skills. Through the development of rhythm a child can gain good muscle growth and motor coordination. The development of fundamental motor skills is associated with the development of rhythmic ability. The development of a timing control mechanism is essential for learning rhythmic coordinated movements, as a lack of timing control may result in poor rhythmic movement skills as has been found in clumsy children. Skilled movements require precise timing in the activation of the various muscles involved in the movements.

The aim of my study was to determine whether eleven 30-minute sessions of metronome-based coordination training would lead to improvements of gross motor skills. The training programme was based on the theory that rhythm and timing are essential components of coordination. This training enabled the individuals to practise and improve their timing and rhythm and through improving these vital abilities potentially lead to improvements in the performance of a range of motor skills. The training required the children to perform movements in time to a beat. The goal of the training was to make the movement as close to the beat as possible.

Rhythmic Activities

Space

Space is needed for the best development of good rhythmic movement. However, classroom aisles or spaces in the class can be used just as effectively.

Accompaniment

Rhythmic movement experiences require the accompaniment of some type. This can be in the form of:

- Music
- Drum
- Clapping sticks together
- Clapping hands
- Musical instruments, e.g. triangle, tambourine, symbols, piano etc.
- Board dusters and desks
- Plastic bottles with stones in
- Singing
- Metronome

If music is going to be used one must be sure that a definite beat is audible. The use of a drum or drum-like instrument is one of the most effective methods for establishing rhythm. Before the children begin the movement, allow them to listen to the beat so that they can plan their movement.

Basic Movements

Children should learn the even locomotor movements. These movements should occur in space, cover space and should be performed to an even beat. These movements can and should be performed in any direction (forward, backward, sideways, diagonally), at different levels (high-on toes, medium-normal, low-crouched) and to various rhythms (fast and slow). The direction, level and rhythms can be varied throughout the activity.

Wa*lking:* Transferring weight from one foot to the other, but one foot is always in contact with the ground.

Running: Could be regarded as a fast walk, but both feet are off the ground at the same time.

Hopping: springing of the ground with one foot and landing on the same foot. The knee should be bent on landing to prevent jarring.

Jumping: Springing off the ground and landing on both feet.

Leaping: Springing off the ground with weight transfer from one foot to the other. It may be done with long strides, covering distance, achieving height or it could be done in place.

Children should also learn uneven locomotor patterns. The way in which the weight is transferred from one foot to the other causes the movements rhythm to have a long-short quality.

Skipping: The combination of a walk and a hop in and uneven rhythmic pattern. A step forward is followed by a hop on the same foot. The hop is shorter (in time) than the step.

Sliding: Involves moving one foot to the side/forward/backward, and then drawing the other foot up to it, then transferring the weight from one foot to the other.

Gallop: Similar to the slide, except that both feet are off the ground at the same time. This movement is much faster and energetic than a slide.

Children should also experience non-locomotor activities; these activities can be combined with the locomotor activities as the children get older, and more coordinated. These non-locomotor activities include the following movement:

- Push
- Pull
- Twisting
- Stretching
- Folding/bending
- Collapsing
- Swinging arms
- Swaying
- Tapping

- Clapping

Other movements, which can be done on the spot therefore not requiring a lot of space, include movements that I used in my project. The possibilities are endless. Here are some ideas:

- Clapping
    - Both hands together
    - Both hands together on desk/wall/with someone else
    - Alternating hands
    - Crossing midline
- Tapping hand to thigh
- Tapping toes
- Alternating toes
- Tapping heels
- Alternating heels
- Clapping hands to any part of the body
    - Right hand to top of head
    - Right hand to right shoulder
    - Right hand to tummy
    - Right hand to knee
    - Right hand to buttocks
    - Right hand to left shoulder
    - Right hand to left knee
    - Alternate right hand and left hand clapping
- The activities that allow for it can also be done while balancing on one leg
- Alternating hand claps to foot taps
- Clap while marching/walking/jumping/hopping on the spot

Activities such as rope jumping are also brilliant rhythmic activities, and boys should be encouraged to participate. One would find that some of the class will be more advanced than the others and therefore you could group them according to their abilities. Before children progress to being able to jump rope where the rope is going over their heads, they should just jump over a rope that is gently swinging from side to side, or that is moving around in a circle.

Rhythmic activities can also include balls, where balls are bounced, rolled back and forth, thrown and caught.

The use of tinikling sticks can also bring a new experience as well as provide variety to a rhythmic class. These sticks are struck to create a rhythm and the child is required to perform movements over the sticks without getting his/her feet stuck in between the sticks.
Visit: http://learn.sdstate.edu/melissa_mork/sctinikling.htm for more ideas with this simple equipment.

Children's activity songs, especially with the younger age groups are an excellent form of combining movement with rhythm. These songs include old musical games such as Ring-around-a-rosie, London Bridge is falling down and Heads-Shoulders-Knees-and-Toes.
The following are websites where these activities and songs can be found:

- www.successful-homeschooling.com/preschool-action-songs.html
- www.kididdles.com
- www.teachchildrenesl.com/songs

Age Considerations

The younger children, grade R to grade 2 are more concerned with themselves, and therefore enjoy moving in space on their own. Children will gradually become accustomed to moving with a partner or a group. The very young children also enjoy using imaginative movements and identifying with animals and other characters. One could get them to walk like an elephant to a heavy beat, or walk like a mouse to a high soft beat. Other examples are flying like a bird/butterfly, hopping like a bunny/frog, galloping like a horse. For the young children the movements should be kept simple.

One should also reiterate left and right hand side, and incorporate parts of the body. These lessons can even include teaching them the contrasting movement:

- Hard and soft
- Slow and fast
- High and low
- Big and small

As children get older they will also become more coordinated and therefore movements can be combined. For example children can do a *run-run-jump* or *run-run-hop-hop-gallop-gallop-fall.* Allow time for children to decide on their own rhythmic movement patterns to encourage creativity. This can be done is various ways, here are a few ideas:

- Each child can perform their own movements to a set rhythm
- Each child can perform their own rhythm moving through an obstacle course
- Play a follow my leader game, where children take turns to perform a rhythmic movement that the other children will follow

When children appear to be struggling with the activity, or keeping with the rhythm organize the children in a manner that the children who struggle are positioned next to a child that is relatively good. When locomotor activities are being performed it is also a good idea to have a bad mover link arms with a good mover, this way the good mover's rhythm will be passed over to the bad mover.

Lessons

Activities can be done for as little 10 minutes. When these activities are started the children will probably battle to concentrate on one activity for more than a minute, so mix the activities up. This will also prevent boredom.

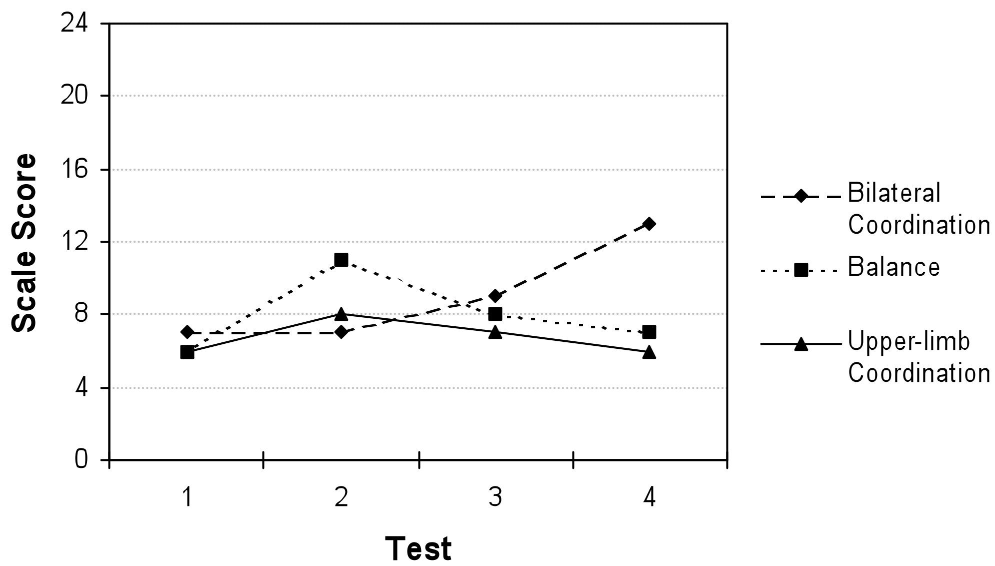
Have fun and enjoy!

Appendix I

Case-by-Case Results

Case 1: Max

Max appeared to be shy, immature and very cautious. Although he was very eager to do things right and do well he also lacked concentration. At the beginning of the intervention, after only a few minutes of training he would get a glazed look in his eyes and get very sleepy. When this happened he would be allowed to relax for a little while, or walk/run around or shake his body. With regard to his movement, in the beginning he made very big circles with his arms and hit really hard, but after stressing small controlled circles and hitting softly he got better and better. Max required a lot of hand over hand assistance. He also battled with identifying left and right sides of his body, which may be an indication as to why his bilateral coordination point scores were so weak, however this improved after the intervention.

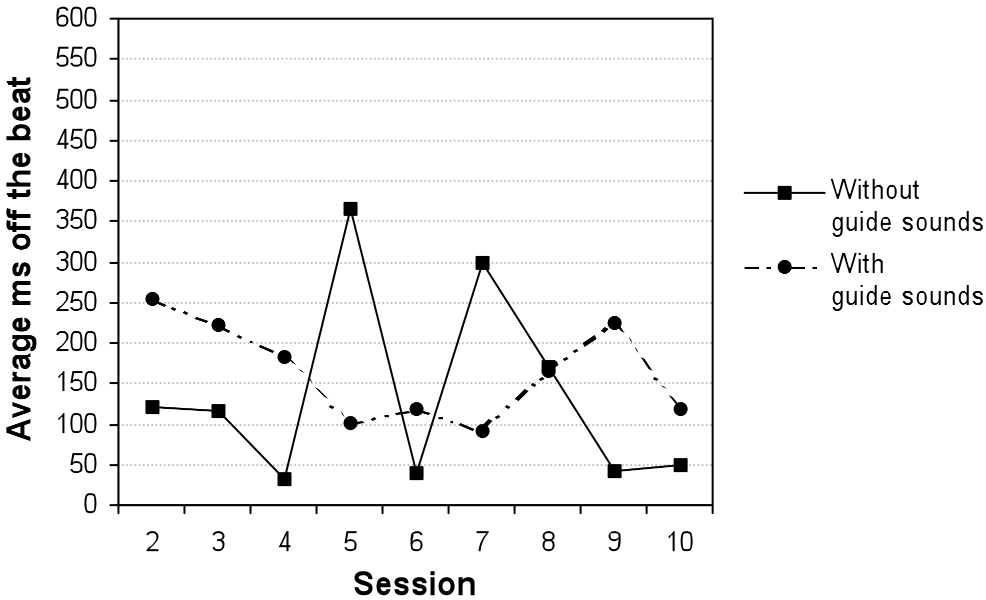


The scale scores reported for Max on each of the three BOT-2 subtests.

Max's the scale scores indicate that bilateral coordination was the only variable that showed any improvement after the intervention period.

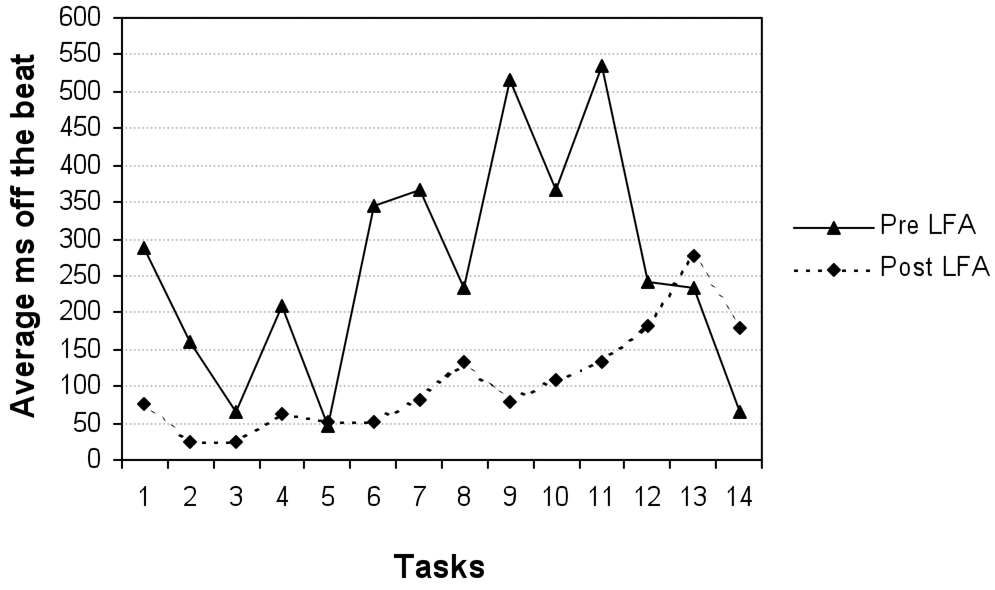
Max's scores on the each of the subtests for each test session in relation to the maximum points possible on each subtest

Subtest	Total Points Possible	Point Scores			
		Baseline Test 1	Pre-test Test 2	Post-test Test 3	Retention Test 4
Bilateral Coordination	*24*	13	14	18	22
Balance	*37*	24	31	28	27
Upper-limb Coordination	*39*	23	28	25	23



Max's SFT results over the 10 sessions of the intervention programme.

Max progressed well through the intervention as the scores on the SFT improved. Most times he was better at the SFT without guide sounds, except in session five and seven. This could be due to many factors of which concentration and motivation could be some of the reasons.



Max's pre- and post-test performance on each task of the LFA.

Initially Max had significantly poor timing and coordination difficulties as his scores in the pre-LFA on most of the tasks placed him in the "severe deficiency" to "extreme deficiency" categories. Max's upper and lower-limb scores were weak, with the lower-limb (especially tasks 6, 7, 8, 9, 12 and 13) and bilateral (tasks 11 and 12) scores being very poor. Max improved his scores on most of the LFA tasks after the intervention period, however his upper-limb scores (tasks 2 and 3) were his best performances.

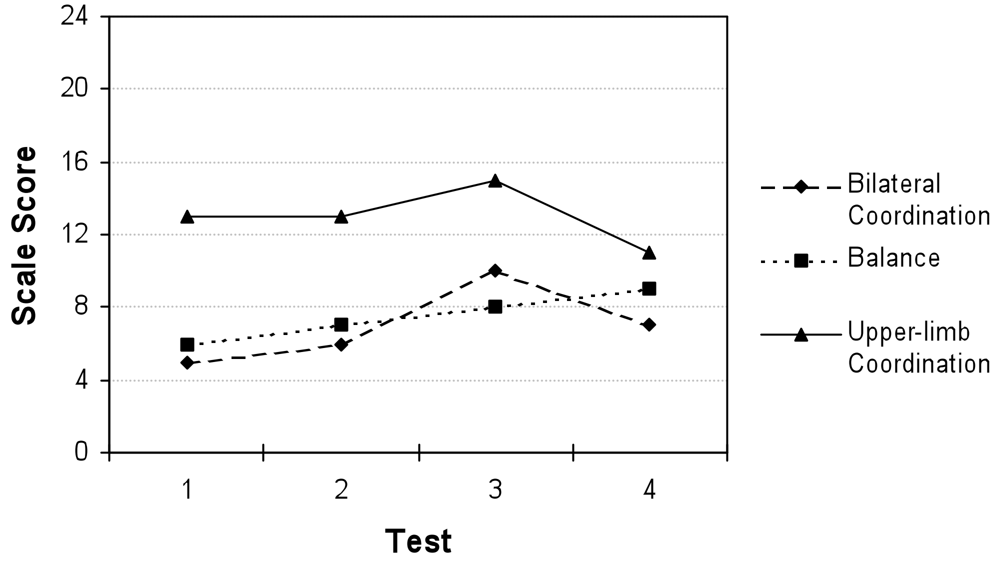
The effects on Max can be summarised as:

- Only the bilateral coordination scores showed real improvement post intervention
- Rhythmic timing improved in almost all the tasks, however the upper-limb movements (tasks 2 and 3) were his best performances

Case 3: John

John was a quiet child who at times just said yes to understanding instructions although he wasn't quite sure what he was suppose to do. He was easily distracted; throughout training it seemed as though he would forget to react to the sounds. John consistently performed worse on the SFT with guide sounds.

During training it appeared that he got confused by the guide sounds, however he did improve over time. He required hand over hand training in the first sessions, but by the end he was easily performing all the exercises on his own. This child had very poor control over his lower limbs, while performing the tasks his legs would appear to “forget” what they were doing which would require the researcher to stand next to him and perform the tasks with him to prompt the correct movements. This behaviour improved with training as he got better and better.

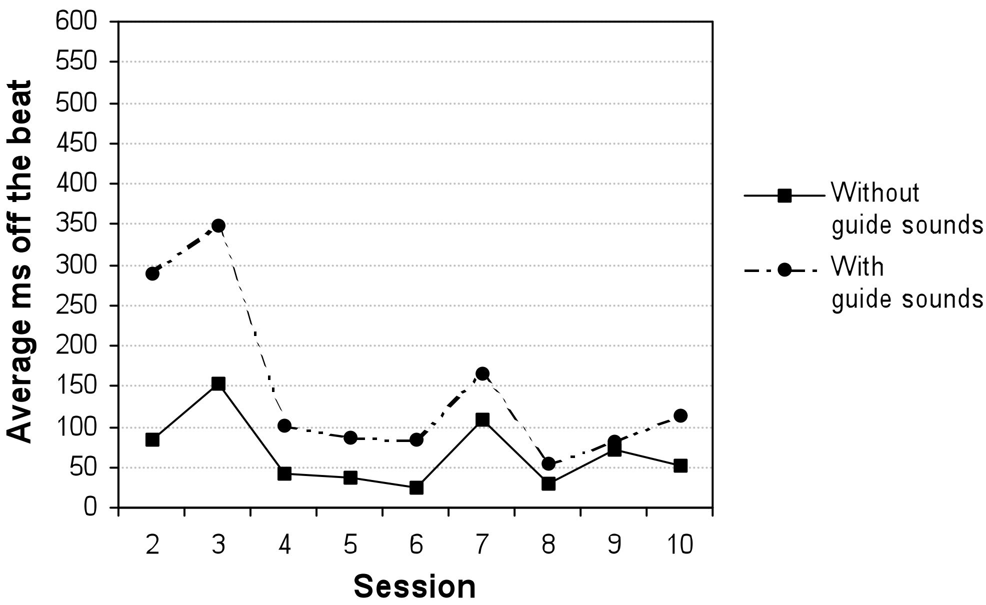


The scale scores reported for John on each of the three BOT-2 subtests.

John initially performed very poorly in both balance and bilateral coordination tasks. Throughout the experimental period he appeared to improve his performance in all the variables over all the tests, except the last test (test four), though there is a notable decrease in the scale score on both the upper-limb coordination and bilateral coordination subtests the decrease in the point scores is not as dramatic.

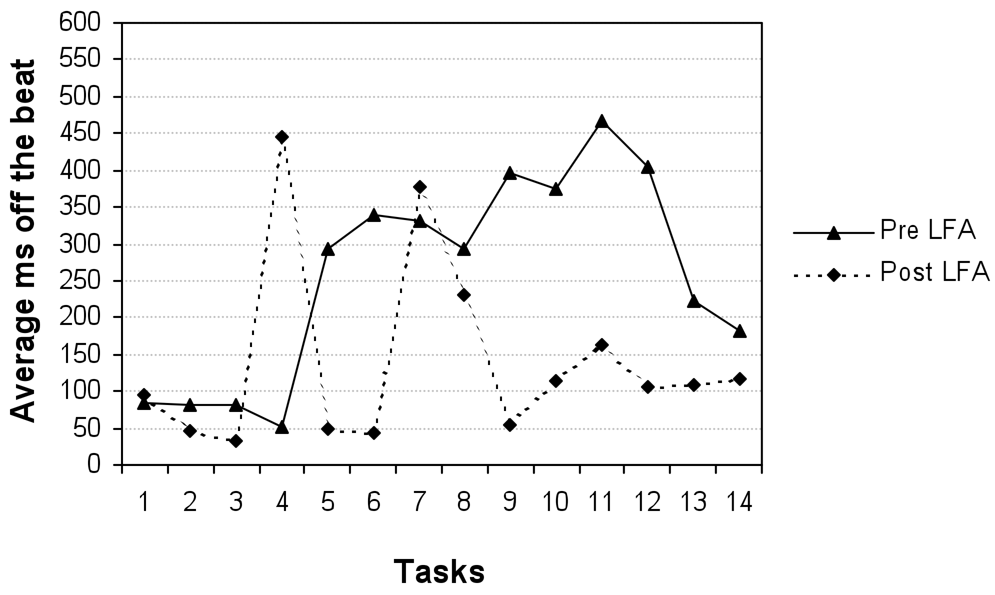
John's scores on the each of the subtests for each test session in relation to the maximum points possible on each subtest

Subtest	**Total Points Possible**	**Point Scores**			
		Baseline Test 1	Pre-test Test 2	Post-test Test 3	Retention Test 4
Bilateral Coordination	*24*	12	15	21	18
Balance	*37*	26	28	29	30
Upper-limb Coordination	*39*	36	36	37	34



John's SFT results over the 10 sessions of the intervention programme.

John improved his rhythm and timing throughout the course of the training. One can see that he struggled with the guide sounds more than without them, however both improved and the SFT task with guide sounds improvement shadows that of the task without guide sounds. Perhaps if the training period was longer John would eventually have mastered the guide sounds and would have been able to use them more effectively.



John's pre- and post-test performance on each task of the LFA.

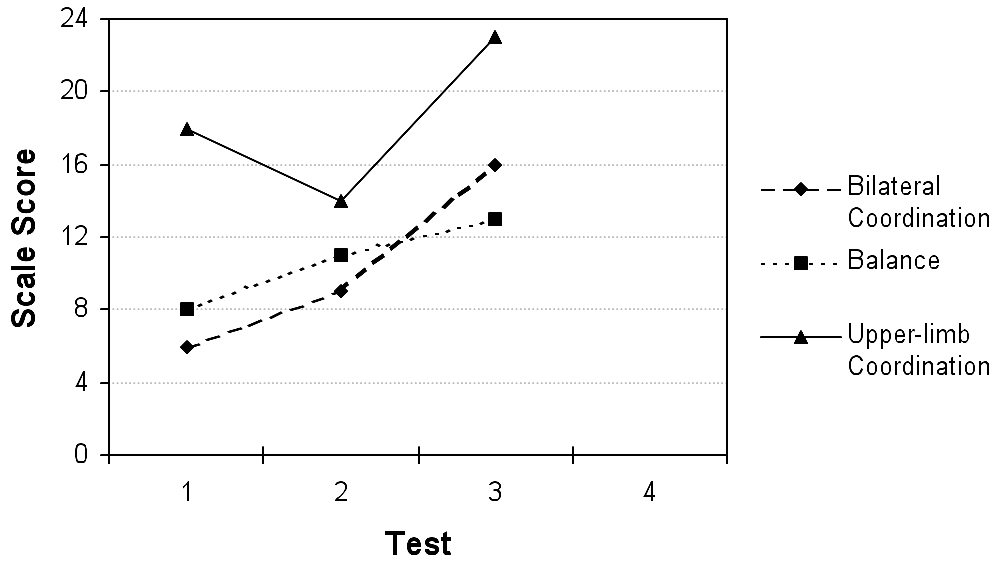
John's scores on the pre-LFA indicate that he struggled with lower-limb (tasks 5 to 9), bilateral (tasks 10 and 11) and balance (tasks 12 and 13) tasks. His scores for these tasks indicate that he has an "extreme deficiency" in rhythm and timing on these tasks. In the post-LFA John showed huge improvement on most of his scores, which indicate that he progressed well through the intervention. A possible reason for the low score on task 4 and task 7 in the post-LFA is that he lost concentration during these tasks, and therefore couldn't get back on the rhythm which resulted in the poor scores.

The effects on John can be summarised as:

- Improvement in all three variables measured by the BOT-2, however this was not strongly retained after the retention period.
- Improved rhythm and timing in most tasks
- Rhythmic movements became more flowing and coordinated

Case 4: Mary

Mary initially struggled with the guide sounds, but once she understood them and learnt how to discriminate between them, her training became better and better. During training her lower-limb movements did not appear to be as coordinated as her upper-limb movements. For the balance tasks during training she initially needed to hold on to the back of a chair, but was quickly weaned from this. Mary's high scores in the initial SFT and LFA left little room for improvement, however she exceeded the researchers expectations and showed superior performances on a number of tasks during the training sessions. Mary was not present for the last testing session as she was absent from school.

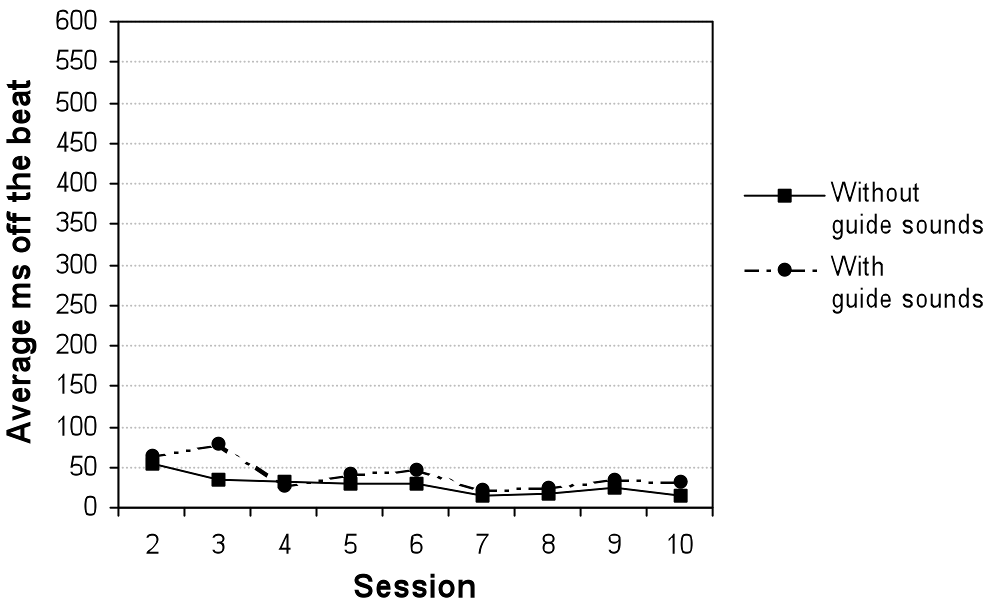


The scale scores reported for Mary on each of the three BOT-2 subtests.

Mary's scores indicate that all three variables that were assessed improved after the intervention. There is a slight improvement in balance and bilateral coordination on the second test which indicate that familiarisation with these subtest items could have taken place. Mary achieved the highest possible score in the upper-limb coordination subtest , as seen in the table containing Mary's point scores. Although the scores do not show vast improvements she did initially score relatively high.

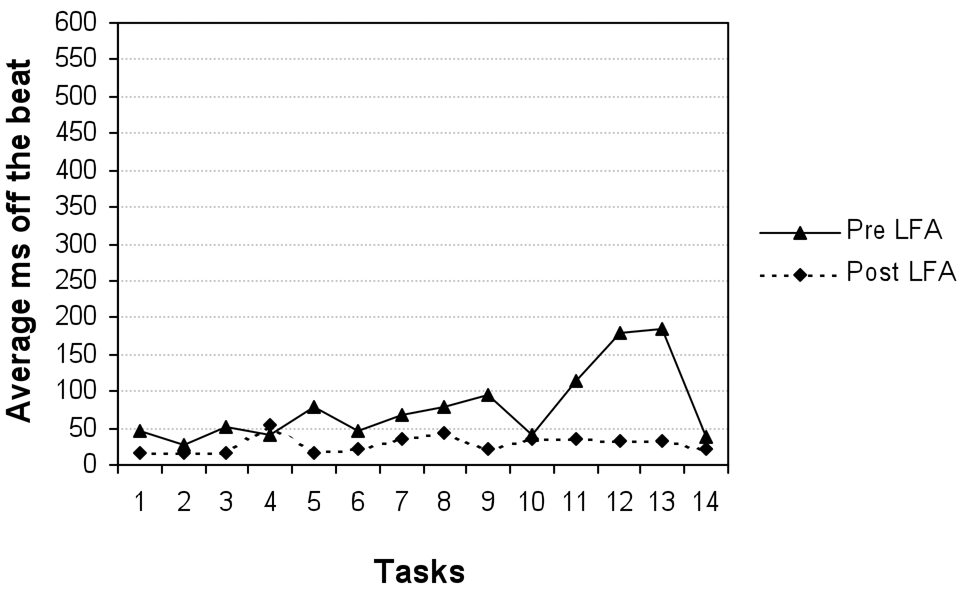
Mary's scores on the each of the subtests for each test session in relation to the maximum points possible on each subtest.

Subtest	**Total Points Possible**	**Point Scores**			
		Baseline Test 1	Pre-test Test 2	Post-test Test 3	Retention Test 4
Bilateral Coordination	*24*	16	20	23	
Balance	*37*	30	32	33	
Upper-limb Coordination	*39*	37	35	39	



Mary's SFT results over the 10 sessions of the intervention programme.

Mary initially performed very well in the SFT as her scores were rated in the average category. Her performance with the guide sounds was not as good as that without the guide sounds, however she improved in both tasks. She achieved extremely good scores from session seven onward. Scores below 26 milliseconds off beat show performances of superior rhythm and coordination.



Mary's pre- and post-test performance on each task of the LFA.

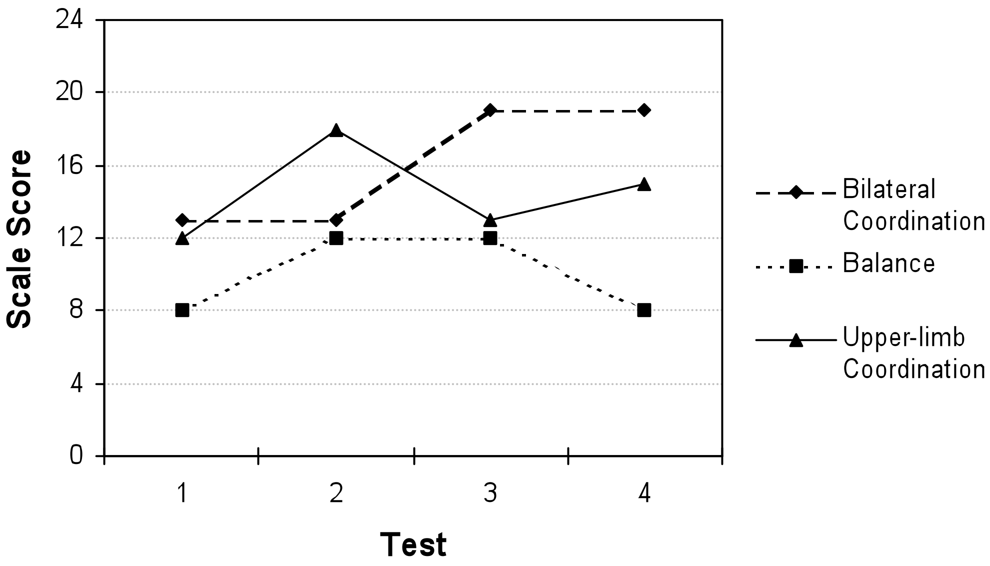
The pre-LFA revealed that the tasks involving balance (tasks 12 and 13) were her weak point. Her balance during training improved and this is shown in the post-test results. Most of Mary's post-LFA results indicate that she reached the exceptional and superior categories in all the tasks.

The effects on Mary can be summarised as:

- Improvements in the three variables measured by the BOT-2 subtests post-intervention.
- Exceptionally good rhythm and timing.

Case 6: Peter

Peter was a child who got distracted by his thoughts very often and constantly needed reminding to try his hardest and listen to the beat. It took him a while to grasp the concept of clapping to the rhythm, but once he did he improved his performance during training. At the beginning of the training his motions were slightly spastic in nature, where it seemed that his arms or legs would spontaneously start moving in the wrong direction, but with training his movements became easier. Early on in the training he required hand over hand assistance to get the movements started, this then progressed to clapping together, but by the end he was performing all the movements with no assistance. The tasks requiring bilateral coordination were a struggle. While one arm was busy performing the task the other would be doing smaller movements at his side. However this improved over the course of the training. In the last two sessions he appeared to improve his understanding and focus during training, and during training his performance improved.

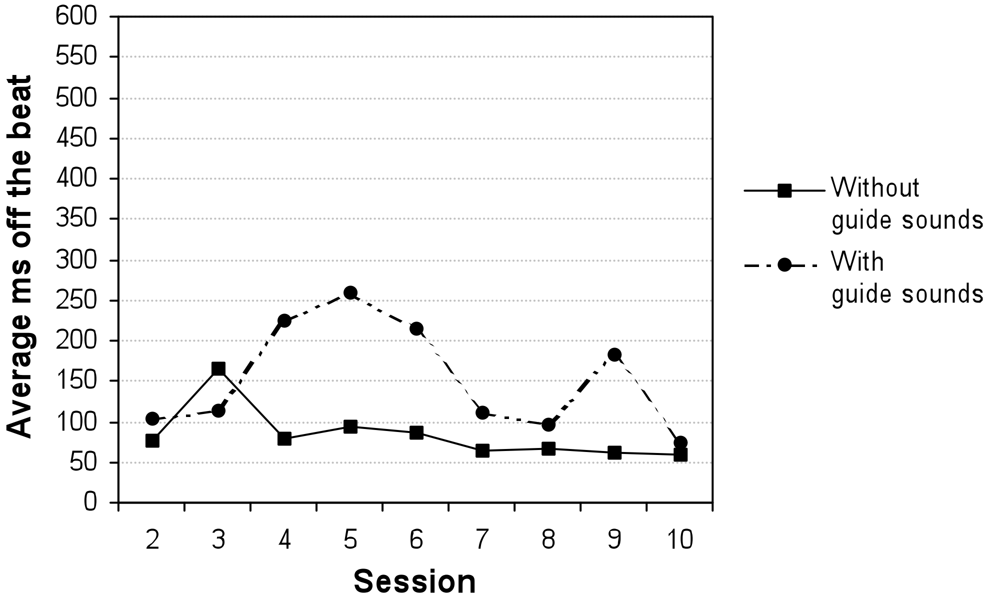


The scale scores reported for Peter on each of the three BOT-2 subtests.

It appears that only Peter’s bilateral coordination showed an improvement after training, and this improvement was maintained after the retention period. The other variables show no improvement, and even a decrease in performance, however these subtests are influenced by a number of factors, especially concentration and motivation which this child really battled with. The inconsistency of the scores indicate that Peter’s performance can vary greatly.

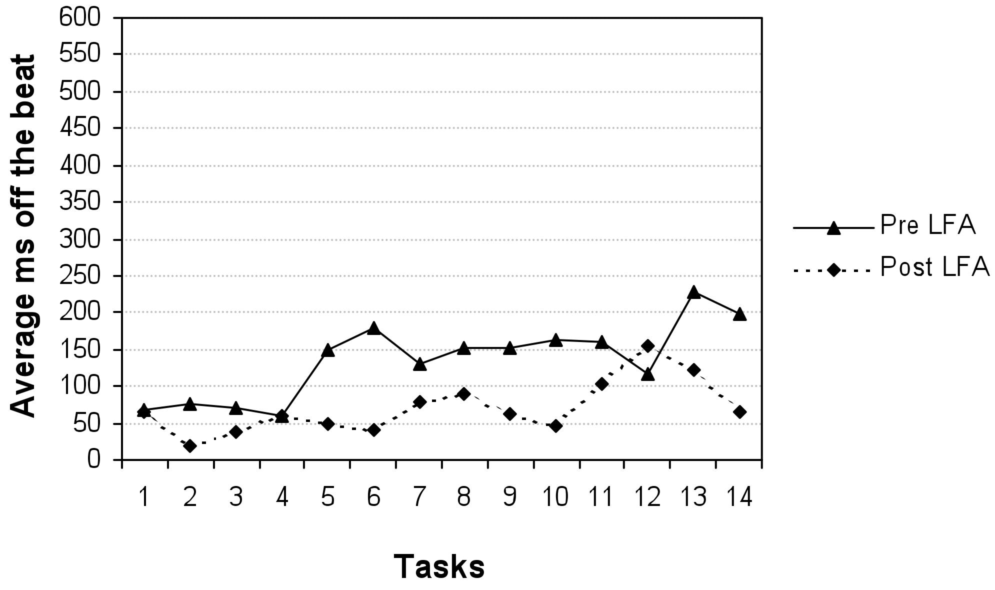
Peter’s scores on the each of the subtests for each test session in relation to the maximum points possible on each subtest

Subtest	Total Points Possible	Point Scores			
		Baseline Test 1	Pre-test Test 2	Post-test Test 3	Retention Test 4
Bilateral Coordination	*24*	22	22	24	24
Balance	*37*	29	32	32	29
Upper-limb Coordination	*39*	35	38	36	37



Peter’s SFT results over the 10 sessions of the intervention programme.

Peter showed small improvement over the course of the training period, where he mostly scored between 50 and 100 ms off the beat in the without guide sounds task on the SFT. Peter struggled with the guide sounds, as is depicted in as these scores are mostly over a 100 ms off the beat.



Peter's pre- and post-test performance on each task of the LFA.

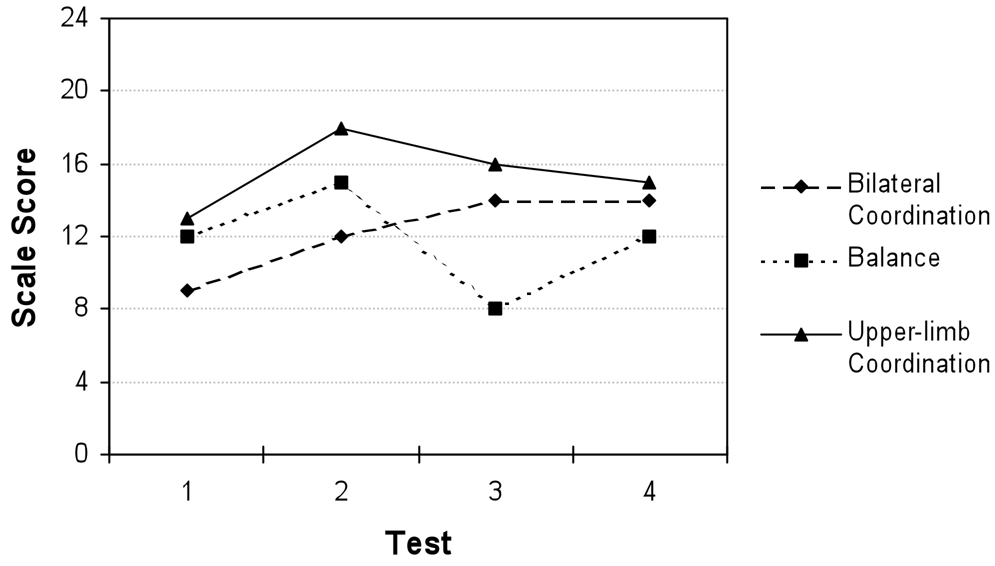
The pre-LFA scores indicated Peter had more difficulty with his lower-limb (tasks 4 to 13) coordination than that of his upper-limb (tasks 1, 2, 3 and 14) coordination. Most of these scores improved after the training period, although there is still room for improvement. Peter would potentially benefit from more training sessions, as this would not only help his coordination, but his concentration and focus as well.

The effects on Peter can be summarised as:

- Improvement in bilateral coordination
- Improvement in rhythm and timing
- Demonstrated smooth controlled movements by the end of the intervention

Case 7: Harry

Harry caught onto the guide sounds and rhythmic movement relatively easily, so progressed very well during the training. He appeared to have sporadic lengths of concentrations. Some days his focus during training was lacking, and needed constant reminding to concentrate and listen carefully to the beat. For the first two sessions he was assisted by the researcher clapping with him. His left/right identification was poor, this would have affected his training as it relied on differentiating between the guide sounds in the left and right ears as feedback. Before training in every session he was required to identify his left and right sides of his body, and by the end he was capable of doing this.

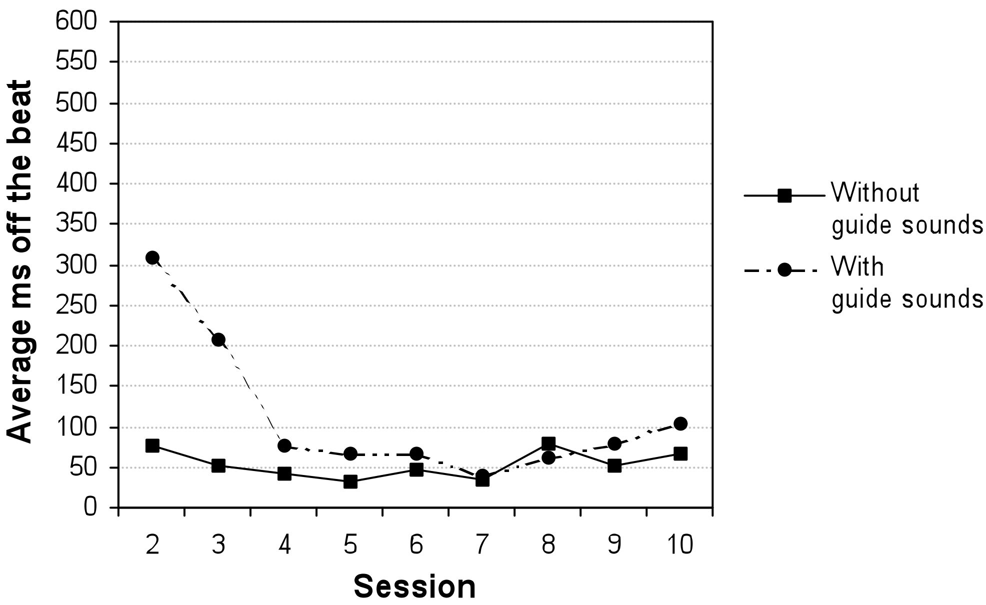


The scale scores reported for Harry on each of the three BOT-2 subtests.

It appears that Harry’s balance and upper-limb coordination got worse after the training, while the bilateral coordination showed a small improvement. The decrease in scores could have been due to concentration and lacking motivation as this child appeared to have limited concentration spans. Bilateral coordination does appear to slightly improve over the study period, although the improvement between time two and three does not appear to be substantial, and therefore one is not able to say that the improvement is due to the intervention.

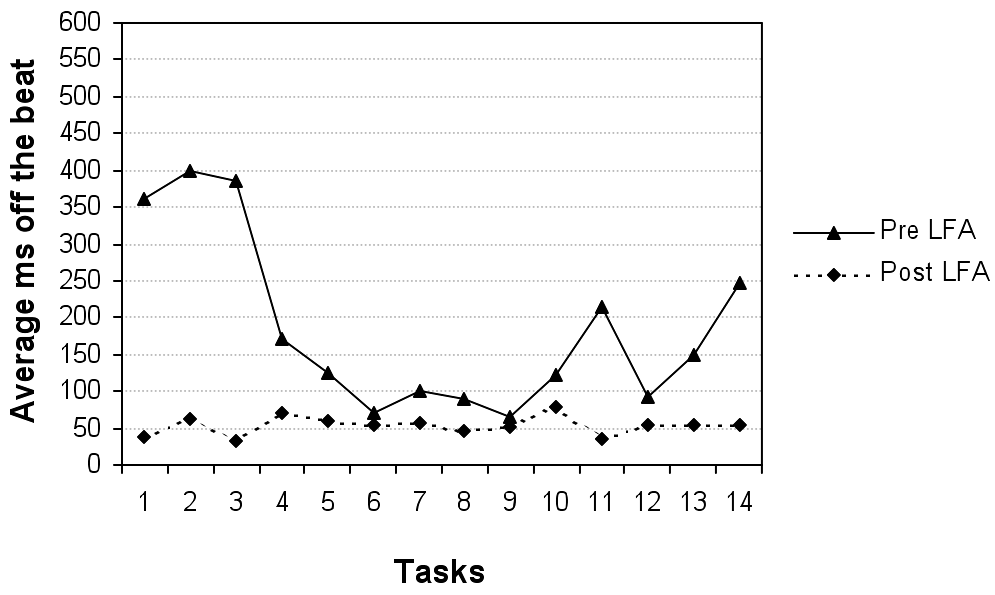
Harry's scores on the each of the subtests for each test session in relation to the maximum points possible on each subtest

Subtest	**Total Points Possible**	**Point Scores**			
		Baseline Test 1	Pre-test Test 2	Post-test Test 3	Retention Test 4
Bilateral Coordination	*24*	16	19	21	21
Balance	*37*	31	33	26	31
Upper-limb Coordination	*39*	33	37	35	34



Harry's SFT results over the 10 sessions of the intervention programme.

Harry's rhythm and coordination appear to improve throughout the intervention sessions as the scores on the SFT improve. Harry initially struggled with the guide sounds (sessions two and three), but by session four he appears to have learnt the guide sounds and was able to use the guide sounds' feedback to improve his accuracy.



Harry’s pre- and post-test performance on each task of the LFA.

The results of the post-LFA indicate that Harry’s rhythm and coordination of all his limbs improved, especially his upper-limb coordination which were the weakest in the pre-LFA (tasks 1, 2, 3 and 14). His improvement is very encouraging as his scores are all ”average” or “above average”, with three scores (tasks 1,3 and 11) falling into the “exceptional” category.

The effects on Harry can be summarised as:

- No real improvement, and even a drop in performance in the three variables measured by the BOT-2 subtests.
- Improvement shown in rhythm and timing, especially in the upper-limb tasks.